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NATIONAL WEATHER SERVICE

HEARING

BEFORE THE

NATIONAL OCEAN POLICY STUDY

OF THE

COMMITTEE ON COMMERCE, SCIENCE, AND TRANSPORTATION
UNITED STATES SENATE

ONE HUNDRED FIRST CONGRESS

FIRST SESSION

ON

NATIONAL WEATHER SERVICE

OCTOBER 26, 1989

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NATIONAL WEATHER SERVICE

THURSDAY OCTOBER 26, 1989

U.S. SENATE,
COMMITTEE ON COMMERCE SCIENCE, AND TRANSPORTATION,
NATIONAL OCEAN POLICY STUDY,
Washington, DC.

The committee met, pursuant to notice, at 9:35 a.m., in room SR-253, Russell Senate Office Building, Hon. Albert Gore, Jr., presiding.

Staff members assigned to this hearing: Penny Dalton and Mike Nussman, professional staff members; and Louis Whitsett, minority staff counsel.

OPENING STATEMENT BY SENATOR GORE

Senator GORE. The committee will come to order. I would like to welcome our witnesses and guests and get this hearing underway.

We are here to talk about the weather, as the old cliche goes, and more precisely about the National Weather Service, climate monitoring, and weather-related programs.

Talking about the weather is something, of course, we all do every day, regardless of where we live or what the climate is in our particular community or neighborhood. The weather affects everything about the way we live.

It is, of course, far more than a topic of conversation. In my own state the threat that a National Weather Service station at Knoxville's McGee-Tyson Airport will be closed raised serious concerns about aviation and commerce. The National Weather Service station is critical to the 19-county region and the safety of the airport's travelers.

I use that only as one example. This year weather-related programs will cost each U.S. taxpayer about $1.50. As a nation we will spend more than $350 million.

By the end of today's hearing, I hope we will have a much better idea of what we are getting for our money.

Weather events have influenced human behavior for as long as we have lived on this planet. In primitive societies those impacts were local and direct. Temperature and rainfall patterns affected the availability of water and food supplies, and severe storms threatened human safety and damaged property.

In some cases weather conditions appear to have changed the future of whole societies causing mass migrations as people left their homes to seek more friendly surroundings.

We are beginning in this century to see environmental refugees repeating that pattern. And many fear that because of global climate change, we will see a surge of environmental refugees.

In today's societies we actually are more rather than less sensitive to the effects of weather even though it may not seem that way sometimes because of air conditioning and heating. In actuality public safety and the national economy, agriculture, aviation, ocean shipping, construction, national defense, all are heavily affected by weather and our ability to forecast changes in the weather.

Last year's drought, to take one example, cost our national economy more than $4.5 billion in direct losses. In aviation two-thirds of all flight delays and more than half of all aviation fatalities are weather-related. In urban areas hundreds of millions of dollars are spent preparing for and cleaning up after snowstorms, and half the money is spent preparing for snow that never falls. We could save a lot of money there alone.

This is a particular problem in our country because although many are not aware of it—I was not aware of it until I looked at the material in preparation for this hearing—the United States of America has the highest incidence of severe weather events of any nation in the world. Flash floods, tornados, hurricanes, blizzards and severe thunderstorms pose a greater threat to Americans than to the citizens of any other nation.

In 1988 severe weather claimed the lives of 316 people in the United States and injured thousands. And, of course, this year, this fall, Hurricane Hugo resulted in 23 deaths and cost the nation at least $5.5 billion in direct losses.

So, it is obvious that weather-related losses amount to billions of dollars each year. And while no one claims these losses could be eliminated by improved weather services, they may, in fact, be significantly reduced through more timely and responsive weather information and more accurate forecasts and warnings.

So, today's hearing will center in large part on ways to achieve those goals. A glance at the trends in natural hazard statistics indicates that the past investment to improve forecasting and increase public hazard awareness has been money well spent, and we have saved hundreds of lives.

For example, in the United States from 1970 to 1979, each year tornados kill 100 people on average. By contrast, since 1980, although the incidence of tornados has remained just about the same, the average number of deaths has been reduced to less than 30. This drop can be attributed to more accurate warnings provided farther in advance by the Weather Service with improved prediction techniques. And, of course, to increased public awareness and confidence in those forecasts.

Similar dramatic reductions have been achieved for other severe storm events. Over the past 20 years lightning has claimed 88 American lives each year on the average, and that figure has been dropping as well. Similarly, the 20-year average for flash flood fatalities is 164. That number has been down in the 30–40 range, so we are seeing some dramatic benefits from our investment in improved weather prediction.

While we must continue our efforts to prevent the loss of even a single life, the success of the weather service in protecting human well-being and minimizing weather-related losses should be recognized and commended.

Turning to modernization of the weather service, I note that the plan released earlier this year by Commerce Secretary Robert Mosbacher marks the first time that a systematic effort has been made to improve our public warning systems. It is an important effort that is long overdue.

However, at the same time, we cannot sign a blank check, and we need to know exactly where the money is coming from. A number of concerns have been raised about both the technology and the structure of the weather service which must carry us into the next century.

We will face unprecedented challenges in the future and, of course, any discussion in this day and time of weather prediction and the National Weather Service must take place within the context of dramatic changes in the global climate. Such changes will have consequences for weather prediction as well.

One of our witnesses later in the hearing will tell us about the increased severity of hurricanes that can be expected to accompany warming of the oceans. While it is impossible to say a drought in any given year is caused by global warming, it is, however, possible to say that the incidence of such droughts will almost certainly increase with global warming.

In the same way, while it is impossible to say that Hurricane Hugo or any other specific powerful hurricane achieved its intensity because of global warming, nevertheless it is possible to say that as the oceans warm, the incidence of such severe hurricanes will increase steadily.

So, I look forward to today's hearing and before going to our witnesses, I want to recognize the Senator from Alaska, Senator Stevens.

OPENING STATEMENT BY SENATOR STEVENS

Senator STEVENS. Thank you very much, Mr. Chairman. I am pleased that you scheduled this hearing and pleased to see Dr. Knauss and Dr. Friday and Dr. Sheets here.

I have provided for you there—I think the gentlemen at the table can see it—maybe the people in the audience cannot—an overlay of the state of Alaska on top of what we call the "South 48" states. The reason I have done this is I have just had an overwhelming amount of mail from my constituents concerning the proposed modernization program of the weather service.

That map shows you the weather stations that are in the south 48 states that would be within the land mass or the islands off of Alaska that are so vital to us. There are 38 such red pins within the superimposed map, indicating that if the land mass of Alaska were in the south 48, it would have 38 stations, weather stations under the modernization program of the weather service.

I am sad to report to you that there are only three left after the modernization program. You have to recall that our state has very few roads. We have fewer roads in Alaska than there are in King

County, Washington. We stretch, as you see, 3,000 miles in width and 1,900 miles in depth. The Aleutian chain goes out 2,400 miles from the mainland, and it is the home of the first and second largest fish-landing ports in the United States and two of the largest fishing fleets in the world. There will be no weather stations out there at all. There are three on the mainland of Alaska, and Alaskans are really disturbed.

We use airplanes rather than cars. We use airplanes rather than trains or buses. We have no land access to over 90 percent of our state in the wintertime. We travel exclusively by air in the wintertime.

Now, I just cannot understand a plan that comes to us with such a reduction. We have already gone through two reductions. We only have 10 left out of over 50 stations that were there when I came to the Senate. Now, very frankly, Mr. Chairman, we just cannot support this plan, and I am going to be pleased to hear the testimony today.

Let me just read to you some of the comments that have come back. Christie Hawk of Paxton, Alaska—that is in the center of Alaska—points out we have eight times the national average of pilots per capita, and she fears the consequences of this modernization for the pilots in her area.

In Valdez, which we are all familiar with now, the charter service out of Valdez points out problems we have had this last year. Vince Mitchell runs that, and he says he makes business decisions daily based on information provided by the weather service in his area. The Mayor of Kodiak points out that that is the largest fishing port in the United States, and we have to combine the operations of small planes and the fishing fleets to be successful, and without a weather station that will be impossible.

I really think there is no way to conduct a hearing like this, representing a state like Alaska, as I do, because my people cannot come down here on such short notice. Yet, somehow you gentlemen there at that table have got to understand that my state will not survive with this change. You can rationalize it in terms of economics all you want, but in our area it is survival.

Unless we find some way to change this plan, I predict it is going to run into very difficult opposition as far as I am concerned. I just cannot support this plan, and I am very surprised to see it, as a matter of fact.

I thank you, Mr. Chairman. Again, I congratulate you for holding this hearing and giving us an opportunity. Since the rack is made for someone else, I will remove my map, Mr. Chairman. I think it does tell a story.

Senator GORE. It really does. If I am not mistaken, Alaska is the westernmost state and the easternmost state.

Senator STEVENS. And the northernmost state.

Senator GORE. I know that part.

Well, we will be pursuing the questions raised by Senator Stevens vigorously in the hearing, just as we will also be pursuing similar questions with regard to our Nation's ability to adequately monitor and develop a better understanding of global climate change.

I have statements that Senators Hollings and Exon would like to have included in the record.

[The statements follow:]

OPENING STATEMENT BY THE CHAIRMAN

Just five weeks ago today, a nation watched anxiously as Hurricane Hugo roared through the Virgin Islands and Puerto Rico and towards the U.S. mainland. For that week, Bob Sheets may have been the most familiar face on our televisions as the Weather Service worked around the clock to track and forecast the storm's murderous path. Then in the final hours before landfall we watched with growing concern as Hugo gained in speed and destructive force and headed straight for Charleston, South Carolina.

As I travelled through the state in the initial hours after Hugo, it was almost impossible to believe the extent of the devastation. The hurricane changed the face of beaches and coastal areas that I have been familiar with since I was a child. Local communities from Folly Beach all the way up to Myrtle Beach—about half the coastline of South Carolina—were altered almost beyond recognition. Estimates of the damage caused by Hugo provide the most telling evidence of its widespread impact—$4 billion in South and North Carolina alone and an additional $1.5 billion in the Caribbean. And these figures are continually being revised upward.

What can we learn from this tragic natural disaster? First and foremost, our public weather warning systems work, and they work well. Through the efforts of the Weather Service and the media at both national and regional levels, in concert with local officials, hundreds of thousands of people were evacuated quickly and efficiently from coastal communities. I am convinced that, without this outstanding cooperation at all levels of government and in the private sector, the death toll of 23 would have been much higher. In fact, the effectiveness of our public warning system stands in stark contrast to the enormous problems and bureaucratic roadblocks we have faced in putting our lives back together after Hugo. I understand that some of the witnesses will discuss ways to improve planning for dealing with natural disasters—I look forward to hearing their suggestions.

The other message from Hugo is the importance of the word service in the title of the National Weather Service—service that was provided at all levels, from Joe Friday and Under Secretary Knauss to the technicians at the Charleston weather office. Bob Sheets did a tremendous job in keeping our nation informed, but he was backed up by an excellent supporting cast.

We must keep the service aspects in mind as we begin to make decisions on the direction of the Weather Service during this critical modernization period. As all of you know, I have pushed hard for many years to procure new weather radars, satellites, and information systems. But at the same time, however, we must balance our need for better weather hardware with the unique services provided by people who are familiar with local needs—throughout the Hugo experience Weather Service personnel were there in Charleston to meet our federal obligations.

I look forward to today's testimony and a thoughtful discussion of Weather Service modernization programs and of new directions for the future.

OPENING STATEMENT BY SENATOR EXON

Mr. Chairman, I thank you for calling today's hearing. As you recall, I requested that Chairman Hollings schedule a hearing earlier this year on the long term and short term plans of the National Weather Service. The response to that request is most appreciated.

There are few activities of the federal government which more directly affect the American people than the work of the National Weather Service. I come from a part of the country where weather information is an essential part of daily life. Our region's economy and ability to work and land largely depend on weather conditions. The great plains are exposed to great seasonal changes. Temperatures can range from double digits below zero to triple digits above. Spring can bring dangerous tornadoes, winter can bring blizzards and summer can bring severe thunder storms. In fairness, I should also add that after even the harshest weather Nebraskans are treated to the bluest skies and the most fertile land. In spite of seasonal extremes, there are relatively few weather related injuries because midwesterners are always alert to weather conditions and react appropriately.

Last year, the Service was on the brink of a financial crisis, with threatened closings of dozens of Weather Service Offices. I rallied Senate opposition to the proposed closings and was delighted that the new Secretary of Commerce responded favorably to spare threatened weather stations.

In years gone by, there was a ritualistic effort by the Reagan Administration to squeeze the weather service. Talk of dramatic reductions, station closings and privatization was regular fare at the Office of Management and Budget. Those efforts have taken a toll. Employees were demoralized and communities were needlessly put through periods of uncertainty.

I have been most impressed with the apparent change in attitude of the new Administration. There seems to be an appreciation of the excellent work of the operations of the Weather Service and a better understanding of the agency's political support.

Given the record of the past Administration, it is understandable that the long term technology program is now viewed with some concern and suspicion. Advances in technology are most welcome and needed, however, I intend to keep an eagle eye on the long term program to assure that the promise of new technology is not a Trojan horse for reductions in service and safety.

Thank you, Mr. Chairman.

Senator GORE. Dr. Knauss, you are our first witness on this panel, and I want to thank you for going through some significant trouble to change your schedule in order to be with us today. We appreciate that very much.

You are joined on this panel by Dr. Joe Friday, Assistant Administrator for Weather Services with NOAA; and Dr. Robert Sheets, Director of the National Hurricane Center from Coral Gables, Florida.

Of course, John Knauss is Under Secretary of Commerce for Oceans and Atmosphere with NOAA.

Without objection, all three of your statements will be included in full in the record. We invite you to proceed with an oral presentation of the essence of it.

So if you would begin, Dr. Knauss, we appreciate your presence.

STATEMENT OF DR. JOHN KNAUSS, UNDER SECRETARY OF COMMERCE FOR OCEANS AND ATMOSPHERE, NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

Dr. KNAUSS. Thank you very much, Mr. Chairman. I will indeed summary my prepared statement.

It does direct itself primarily to the issue of modernization of the Weather Service, what we are doing and how we plan to show the public and the Senate, the Congress, that what we are doing is in the best interest of the people of this country.

In March 1989, Secretary Mosbacher transmitted to Congress the President's Strategic Plan for Modernization and Associated Restructuring of the Weather Service. Implementation of this plan will significantly improve services provided by the National Weather Service. The plan includes: intensive training and education of Weather Service personnel; deployment of proven new observational systems and information processing and communication technologies; and by automating some of our existing systems we can concentrate on analyzing, predicting and issuing timely warnings of severe weather.

The new observing system includes three parts: the automated observing system; the next generation of weather radar; and advanced geostationary and polar orbiting satellites.

The automated observing equipment will provide continuous uniform surface weather observations. The new radar coverage will blanket the entire Nation east of the Rockies and provide significantly improved coverage in the mountain regions of the west, a significant improvement over our present coverage.

These new radars will identify not only water droplets and clouds but characteristic wind patterns in and around severe thunderstorms and summer systems, and will increase the lead time and accuracy of tornadoes, severe thunderstorms and flash flood warnings and hopefully further reduce the loss of life we have in these severe storms.

With the advanced geostationary and polar orbiting satellites, we can better identify, observe and track both the large scale weather systems and the small scale local severe storms.

With these three systems, we anticipate a significant improvement in our ability to issue timely warnings regarding severe weather. In addition, centralized computers at the National Meteorological Center will analyze and provide predictions of the atmosphere on a global scale essential to local forecasters beyond 12 hours.

In the next two years the National Meteorological Center will significantly increase its computer power, which will increase the resolution and accuracy of global predictions and will also improve guidance for local forecasters.

These new systems mean that the local weather forecasting offices will receive much more detailed and frequent information for the local offices to assimilate this increased information flow.

The Advanced Weather Interactive Processing System, a terrible name, will be the local processing system which assists the forecaster with warnings and forecasts through communication, data collection, data analysis, graphic displays, improved forecast techniques and dissemination of products.

By automating much of the labor intensive forecasting processes, AWIPS will provide the professional forecaster with more time to concentrate on the warning and forecasting problem.

Weather forecasting offices in general will be located near the radar sites and will be staffed with professional meteorologists and meteorological technicians. Uniform warning services over the area of responsibility will be ensured by providing the forecasters with access to all meteorological data for that area as well as appropriate guidance products generated centrally.

Meteorologists in each of these offices will have the knowledge, skills and ability to take full advantage of the volume and variety of observation data which will be available to them.

Deployment of new technological applications of advances in meteorological sciences require Weather Service employees to be fully trained and to understand the use of information available to them.

Mr. Chairman, I recognize the Congress and the public are concerned about the adequacy of our coverage and service as this modernization plan goes forward. We are, too. To assist us, the National Weather Service is securing an independent review of these activities in the form of a contract with the National Academy of Engineering. The purpose of the review is to help ensure the successful demonstration and acceptance of modernized restructured National Weather Service operations by testing, demonstration and certification plans and by independently reviewing the data collection and interpretation process.

The process by which the National Weather Service will comply with the requirements of section 408 of P.L. 100-685 is in three parts: First, there is the notification of future plans of modernization and the associated restructuring;

Second, there is the notification of the intent to certify; and

Finally, there will be the certification.

Certification will be the process by which the National Weather Service will provide evidence based upon operation and demonstration of modernized National Weather Service operations which support the conclusion that no degradation of services will result from such action.

The process will go as follows. Each year, the Secretary of Commerce will submit to the National Weather Service a national implementation plan for the following three years. In other words, you will have essentially a rolling three-year program.

This plan will include our proposed significant modernization associated restructuring events, which will include the following kinds of things: changes in facilities; staff at local offices; operations and services; relocation and decommissioning of old technology; and commissioning of new technology.

This notification is intended to keep the Congress and users of Weather Service informed in advance of all future significant changes in the National Weather Service operations. Each year when the national implementation plan is submitted to Congress, it will also include notification of which offices it intends to certify during the following year, a detailed comparison of services provided to the affected area before and after office closures, consolidations, automation or relocation plus any recent expected modernization of National Weather Service operations which will enhance services to the affected areas. These will all be included in the site implementation plans which cover the affected area.

The management of this transition will be a complex effort involving every level of the National Weather Service. Accordingly, we have established what we call a Transitional Program Office to provide the organizational focus for the entire transitional program. This office will draw upon the technical staff of our headquarters, regional offices, field stations, et cetera.

When all these steps have been completed for the closure, consolidation, automation or relocation of a Weather Service office, a certification statement will be prepared by the region responsible for that office. The statement will be endorsed by the National Weather Service headquarters, by me and the Secretary of Commerce. Then it will be delivered to Congress.

Let me close, Mr. Chairman and Senator Stevens, by emphasizing that the modernization and associated restructuring of the National Weather Service represents a major transition from today's operations to those of the future. The National Weather Service will be making every effort to ensure that the quality of services remains constant during this transition. We are looking forward to working with the Congress as described in P.L. 100-685 to ensure that modernization of the National Weather Service is a success.

That concludes my statement, and I will be glad to attempt to answer any questions you may have. I have Dr. Friday with me. If the questions get too technical, I hope I can call on him to help.

Thank you, sir.

[The statement follows:]

Statement
of

Dr. John A. Knauss
Under Secretary for Oceans and Atmosphere
National Oceanic and Atmospheric Administration
U.S. Department of Commerce

before the

National Ocean Policy Study
and the
Committee on Commerce, Science and Transportation
United States Senate

October 26, 1989

Mr. Chairman and Members of the Committee:

I am pleased to appear before you on behalf of the National Oceanic and Atmospheric Administration (NOAA), U.S. Department of Commerce, to discuss the modernization and associated restructuring of the National Weather Service (NWS).

In March 1989, Secretary Mosbacher transmitted to the Congress the President's Strategic Plan for Modernization and Associated Restructuring of the NWS. Implementation of this Plan will significantly improve the services provided by NWS. The Plan calls for putting recently developed meteorological science into practice through the training of NWS personnel and the deployment of proven, new observational, information processing, and communications technologies. By reliably automating our existing observation systems, our personnel will then be able to concentrate on analyzing, predicting, and issuing timely warnings of severe weather.

The new observing systems include the Automated Surface Observing System (ASOS), Next Generation Weather Radar (NEXRAD), and advanced geostationary and polar orbiting satellites. ASOS will provide continuous uniform weather surface observations and will allow forecasters to monitor significant weather changes immediately.

NEXRAD coverage will blanket the entire Nation east of the Rockies and provide significantly improved coverage in the intermountain west. This coverage represents a significant advancement in our ability to observe local atmospheric processes. Unlike current radars which can only detect water droplets within clouds, NEXRAD will identify characteristic motion patterns in and around severe thunderstorms and provide valuable insight into atmospheric processes before damaging weather occurs. This, coupled with an improved understanding of atmospheric processes, will increase the lead time and accuracy of tornado, severe thunderstorm and flash flood warnings.

Advanced geostationary and polar orbiting satellites will identify, observe, and track both large scale weather systems and small scale local severe storms. This will include winter storms producing freezing precipitation and snow, hurricanes moving northward along the Atlantic coast, and tornado producing thunderstorms. When combined with the other new observing technology, we anticipate a significant improvement in our ability to issue timely warnings regarding severe weather.

Centralized computers at the National Meteorological Center (NMC) analyze and provide predictions of the atmosphere on a global scale. The guidance provided from these predictions is essential to local forecasts beyond twelve hours. In the next two years, NMC will increase to supercomputer power. The new computer capability will increase the resolution and accuracy of the global predictions and will also improve the local guidance.

The Advanced Weather Interactive Processing System (AWIPS) will be the local processing system which assists the forecaster with warnings and forecasts through communications, data collection, data analysis, graphic displays, improved forecast techniques, and dissemination of products. Through automation of labor intensive forecasting processes, AWIPS will provide the professional forecaster with more time to concentrate on the warning and forecast problem. It also will provide the forecaster with integrated NEXRAD, ASOS, and environmental satellite data. This integration of data sets will enable the NWS to improve warning and forecast services.

Weather Forecast Offices (WFO's), in general, will be located near NEXRAD sites, and will be staffed with professional meteorologists and meteorological technicians. Uniform warning services over the WFO's area of responsibility will be ensured by providing the forecasters with access to all meteorological data for that area, as well as appropriate guidance products generated centrally. Meteorologists in each WFO will have the knowledge, skills, and ability to take full advantage of the volume and variety of observational data which will be available to them in the future.

Deployment of the new technologies and application of advances in meteorological science requires that NWS employees must be fully trained to understand and use the information which will be available to them. Part of this training will deal with the new systems such as NEXRAD and AWIPS, and a part will deal with the recent scientific advances in meteorology.

NWS is securing an independent review of these activities in the form of a contract with the National Academy of Engineering. The purpose of this review is to help ensure the successful demonstration and acceptance of modernized and restructured NWS operations by review test, demonstration, and certification plans, and by independently reviewing the data collection and interpretation processes.

The process by which the National Weather Service will comply with the requirements of section 408 of Public Law 100-685 is in three parts; notification of future Modernization and Associated Restructuring (MAR) significant events, notification of intent to certify, and certification. Certification is the process by which NWS will provide evidence, based upon operational demonstration of modernized NWS operations, which supports the conclusion that no degradation in services will result from such action.

Each year the Secretary of Commerce will submit the National Weather Service National Implementation Plan for the following three years to the Congress. This Plan will include a list of significant MAR events which will occur during the following year on a State-by-State basis. Significant events include changes in facilities; staff at local offices; operations and services; relocation and decommissioning of old technology; and commissioning of new technology. This notification is intended to keep the Congress and users of weather services informed in advance of all future significant changes to National Weather Service operations.

Each year when the National Implementation Plan is submitted to Congress it will also include notification of which offices it intends to certify during the following year. A detailed comparison of the services provided to the affected area before and after office closures, consolidations, automation, or relocation; plus, any recent or expected modernization of NWS operations which will enhance services in the affected area, will be included in the Site Implementation Plans (SIP's) which cover the affected area. Evidence, based upon operational demonstration of modernized NWS operations, which support the conclusion that no degradation in services will result from office closures, consolidations, automation, or relocations will be included as part of each demonstration's documentation.

Notification to the Congress of each NWS demonstration will be through the National Implementation Plan.

Management of this transition will be a complex effort, involving every level of the NWS. Accordingly, the NWS has established a Transition Program Office (TPO) to provide an organizational focus for the entire transition process. The TPO will draw upon the technical staff of the NWS Headquarters, Regional Offices, and field stations to prepare the plans necessary for implementing the MAR. The transition plans are in tiers, with the NIP driving plans at the National level, Regional Transition Plans for the six NWS Regions, and SIP's for each office location.

When all the necessary steps have been completed for closure, consolidation, automation, or relocation of a WSO, a certification statement will be prepared by the NWS Region responsible for that office. The statement will be endorsed by NWS Headquarters and the Secretary of Commerce, and then it will be delivered to Congress.

The modernization and associated restructuring of the NWS will represent a major transition from today's operations to those of the future. The NWS will be making every effort to ensure that the quality of services remains constant during this transition. We are looking forward to working with the Congress as described in Public Law 100-685 to ensure that modernization of the NWS is a success.

Mr. Chairman, this concludes my prepared statement. I will be glad to answer any questions you may have.

Senator **Gore**. We will hold off on our questions until all three panelists have finished.

Dr. Friday, you are next. Please proceed.

STATEMENT OF DR. ELBERT W. FRIDAY, ASSISTANT ADMINISTRATOR FOR WEATHER SERVICES, NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

Dr. **Friday**. As contrasted to prepared testimony, Mr. Chairman, I would like to address a few of the concerns that you and others have expressed as results to the modernization.

As Dr. Knauss stressed in the testimony, we, too, are worried about the continuity of services and the improvement of services across the United States as we implement the modernization plan. That is one of the reasons that we want to assure that we take all opportunities to prove conclusively the effectiveness of the science, the effectiveness of the technology, and the effectiveness of the operational structure that we are about to implement.

This is not something that we are starting from paper today with the publication of the strategic plan. It is not something that we are starting with the national implementation plan that will soon be forthcoming to Congress. It is something that we have been working on for the past dozen years within NOAA and within the academic community addressing new and better ways of analyzing, observing and forecasting the weather and flooding events that affect this country.

We have taken actions already in several locations around the country to test components of the modernized weather service. We have facilities at Oklahoma City, at Norman, Oklahoma, associated with the university and the National Severe Storms Laboratory in that location which have tested the radar component of the modernization, and the effectiveness of using that radar data along with other data for improving the ability to forecast severe storms.

I am happy to say that the results of the next generation of weather radar testing that have recently been concluded had some very good news for us. As far as the accuracy of the weather warnings produced using the next generation weather radar data for the state of Oklahoma during the five-month period of the test in the spring and summer of this year, the accuracy of the weather warnings produced by the forecast office using NEXRAD data went from the national average of a little under 60 percent to 91 percent for that particular time.

In other words, our ability to forecast in advance to provide warnings for severe storms and tornados, a national average now of 58 percent, the average used during the NEXRAD using the advanced Doppler radar technology of 91 percent.

Now, I would caution you, sir, that that does not represent the sort of thing that we would expect to have happen as soon as we put that equipment in around the country because the office at Oklahoma City has been working with research Doppler radar now for several years. They have developed a good understanding, a good training in the use of that data, and it represents what we can expect to have with that sort of education and training throughout the country then as we move forward.

That is one of the reasons that Dr. Knauss stressed very carefully that we had to concentrate on an education and training program for all of our staff. It is not only modernizing the technology in some respects, it is also modernizing our own internal abilities to handle the data to understand the science.

In addition, we have been bringing together all of the data sources at the office at Denver, Colorado, now, for the last three years in using components of not only Doppler radar, also current analysis of satellite data, and bringing these all together in prototype equipment of the type that we will be distributing across the country with the AWIPS program that Dr. Knauss mentioned.

We have seen significant improvements in our ability to forecast those snowstorms that are so troublesome to those of us on the East Coast. I have lived through enough of those here in Washington myself, both forecast and unforecast to understand the problem.

To better able to bring into consideration all of the small-scale features that drive the local weather events, one of the things that we are observing as we go forward with the new technology is that the small-scale features in the atmosphere are what drive the severe weather, the so-called mesoscale features.

In the case of Denver, Colorado, we have now begun to understand the physics that occur as the small-scale forcing functions that cause the initiation of severe storms, and we are able to use the new technology to identify the precursors of those so that we are able now to issue storm warnings sufficiently in advance, not the five or ten or 15 minutes that we currently experience, but on the order of almost an hour—in some cases even more—to provide the kind of information.

These tests have been going on. The tests are very encouraging.

Now, I do not want to say that everything is absolutely perfect. We also identified in the NEXRAD testing, for example, that we still have work to do before we have a fully operational system that can be deployed. We decided to test this spring and summer so that we would not delay the overall modernization any more than absolutely necessary.

In doing so, we had to test with the preproduction system that was not full production quality. We had reliability problems with that that we are now correcting and we believe that we have corrected. We also had problems with the technical manuals for maintenance and operation. We are working very diligently on correcting those before we implement this technology across the country.

But, we have proven the technology so far. We have proven the science so far in the applications of that. Now, we have to put forward in the plan as you see coming forward the actual demonstration of that.

We are worried also about the ability to be able to provide quality service to this nation. We will be putting forward, then, a plan or a program in which we will test the entire structure in a nine or a ten station area in the center part of the country. The entire state of Oklahoma, the entire state of Kansas, part of the states of Colorado, Nebraska, Missouri and so on will be included in this regional test so that we can prove to you, to ourselves, to all of our users that we can indeed provide that data.

With respect to the state of Alaska, Senator Stevens, I would like to acknowledge the fact that you have a very impressive map there, and it does indeed show something that we usually tend to forget, and that is the vast expanse of the state of Alaska and the requirement for weather services in that state.

The thing that I am proud to report here is that for the first time the National Weather Service will be implementing good radar coverage in the state of Alaska, whether radar is something that, as you know, we have not had there now, and we are aiming this at covering both the fishing industry along the Gulf of Alaska—indeed we will be placing next generation weather radars around the periphery of the Gulf of Alaska, probably at St. Paul Island to cover the Bering Sea fishing fleet, and also in the interior at Fairbanks to cover the center part of the country.

The width of that increased capability, we feel that we will indeed be able to provide much better aviation weather support than we have been able to provide in the past and be able to provide increased support and improved support to the fishing fleets that are so vital to the economy, not only of Alaska, but to all of the United States.

With that, sir, I think I will end my comments at this time. Thank you, sir.

Senator GORE. Very good. I know we will have some follow-up questions on that.

Dr. Robert Sheets is our third witness.

Dr. Sheets, here lately you have become almost as well known as Bob Ryan, the meteorologist on our third panel.

Dr. SHEETS. Bob had me on the show a few times.

Senator GORE. Maybe that is it, but welcome and please proceed.

STATEMENT OF DR. ROBERT SHEETS, DIRECTOR, NATIONAL HURRICANE CENTER, CORAL GABLES, FL

Dr. SHEETS. It is a pleasure to be here. I think from our perspective representing the tropical belt; that is, from our responsibility from the National Hurricane Center, is not just hurricanes, but it is tropical meteorology, it is tropical weather, it is marine and aviation forecast, essentially from Africa all the way across to 140 degrees west. That is almost to Hawaii and from the Equator northward to about 32 degrees north.

A lot of people overlook our responsibilities when they look at the hurricane center and say well, that is hurricanes. We have a lot of other responsibilities there, and I can certainly understand the problems of lack of information over a large area such as Alaska.

We have an area out there called the North Atlantic that exists from the Equator to 32 degrees north from the U.S. over to Africa where we have one station for four million square miles. That is Bermuda. We do not have one at every 38,000 square miles or so. That is over the continental United States. So, we have got to get on with modernization in terms of the coastal areas with Doppler radars that we are talking about, but also with the new, improved satellite products that we need over the oceanic areas.

If I could, Mr. Chairman, I would like to use a few slides to illustrate our data problems, why we use satellites, why they are so vital to us and then the problems along our coast today, the fact that we have the great increase in populations along our coast, particularly on the barrier islands that we have been testifying before some of the committees over the Barrier Island Acts and so on, and what we perceive as problems that we have in warning those populations. If I can use the slides, please.

Senator GORE. That is from the GOES satellite?

Dr. SHEETS. That is from the GOES satellite. As you can see, it is just last week, October 17, and that is Hurricane Jerry that moved into Galveston, Texas, a very small hurricane. It happened to be that during that hurricane when it was south at 25 degrees north in the Gulf of Mexico as a tropical storm, getting borderline hurricane status, we had two of our Air Force reconnaissance aircraft that had problems, so we missed about an eight-hour period when we did not have that data.

On the basis of some of our satellite imagery, because it was a very poorly organized system, we did not locate it properly. We put up a tropical storm watch. Had we had the reconnaissance data, we would have not put it up for the area along Mississippi and across Louisiana in particular.

So those are some of the problems we have. We were fortunate that this hurricane was relatively small. It was also a category one on our scale of one to five; therefore, it did not do widespread damage because we were only able to provide eight hours of lead time in terms of the forecast of this hurricane making landfall at the strength which it actually made landfall. Fortunately, again because it was small, we did not need massive evacuations, and that was basically sufficient.

There was a hurricane a few years ago in 1900 that was almost the strength of Hurricane Hugo. It was essentially the same strength as Hurricane Hugo. It went into Galveston, Texas in September of 1900. Galveston looked like this before the hurricane, and Galveston looked like this after the hurricane. You can imagine the problems that were there. There were over 6,000 people killed in that hurricane. Estimates go as high as 10,000 people. They had a major problem. About one-third of the population was drowned by that hurricane.

We observe hurricanes in several ways. Our first line of defense is the GOES satellite. We are concerned, as I know you are here, that our GOES satellite technology is not where it should be at this stage, and so we do have some problems in those areas. That is the first line of defense.

The second is the aircraft. You see the NOAA research aircraft superimposed here.

Then the third is the coastal radar, which I have illustrated down in the lower left.

We have had some major advancements in technology as a result of those satellites and the aircraft capabilities to fly into the hurricane.

Here is Hurricane Gilbert from last year as it moved over Cancun. Certainly from the satellite you can see where the center is. I can locate it as well as I can from the aircraft when you have a well-formed eye. If you do not have a well-formed eye, as I mentioned for Hurricane Jerry, that is not possible. We mislocated Hurricane Jerry by over 100 miles by the satellite in the middle of the Gulf of Mexico.

Here we have this, but we do not know what the windfield is down below. As I will illustrate for Hugo, it is very important to know what that windfield is to determine what areas need to be evacuated.

We developed technology to provide the computers on board the aircraft flying into the hurricane to be able to transmit information from the aircraft up to the satellite and back down to the National Hurricane Center, and we plot out the wind, temperature and pressure. Even digitized radar is now in the offing, and we will have that available to us in real time so we can get that in a matter of seconds from when it is actually observed.

For instance, this is the data that came to the National Hurricane Center during Hurricane Gilbert's passage just to the east of Cancun, Mexico. The little white lines there illustrate the pattern that the aircraft flew as it went back and forth through that hurricane. Each one of those little flags indicates the wind speed and wind direction that was measured in there, and then you see the digitized radar from the aircraft that is being displayed there.

We had winds of nearly 200 miles per hour in the north eye wall as that airplane went through there.

Now in the vertical, this is what it looked like on board the aircraft. The aircraft is the little dot in the center of the picture right there. It is going into the board, and then you have the surface down below there. On the right side you see the eye wall on the right side extending from the surface up to about ten miles high. That is the kind of technology we have coming along. The new land-based Doppler radars are going to be able to give us even more of that kind of information as hurricanes make landfall.

Most of you were well aware of Hugo. It looked like this on our satellite as we first sent our airplanes into that storm. Again, we did not know how strong it was, and we underestimated the strength by about 40 miles per hour until the aircraft got there and found out how strong it was. It was moving toward the islands at this stage.

We used the aircraft and satellite in a complementary fashion. The aircraft can give us the detailed information over the storm itself in the core of the hurricane, but it cannot get out in the peripheral areas, and that is where the satellite provide us information out there as well as the general flow patterns over the entire Atlantic. That is what we use to forecast where the hurricane is going to go, that information outside the environment outside the environment of the hurricane itself. Then within the hurricane, what areas need to be warned, how strong is the hurricane going to be.

This is what it looked like as it moved across Guadalupe. Here it is now approaching St. Croix with about 140 mile per hour winds. I am sure you have all seen the coverage there. That is what took place over St. Croix.

Here it is as it moves over the northeast part of Puerto Rico. At this stage it had weakened slightly, 125 mile per hour winds, so we had a lot of damage in Calibra, the islands off the eastern tip of Puerto Rico and the northeast part of Puerto Rico. The rest of the island did fairly well.

As the storm moved on toward the northwest it weakened because of the inflow over the island of Hispaniola but then started to increase here in strength.

At this stage we see the red zone there is hurricane force winds. The orange zone is tropical storm force winds. We are forecasting at this stage that it will go into South Carolina, and we put up a hurricane warning in the red zone, you see, essentially from the Georgia-Florida border up through the middle part of the North Carolina area there with the probability superimposed on that to illustrate the highest likelihood being somewhere around Charleston, South Carolina at this stage. That is when the warning went up.

We then had the highest resolution satellite capability that we have from the GOES satellite that got this picture of the big eye about 50 miles across, and the winds were about 110 miles per hour. As that eye contracted, the storm strengthened to a total of about 135 miles per hour.

Now as we approach Charleston, this is what we saw on our radar. We are able to dial this up, get this back at the Hurricane Center, and look at this in real time, in fact, in time lapse form. However, with Doppler we would also be seeing the winds that are associated with this hurricane, the windfield to be associated with that hurricane in a much more complete fashion than we are able to get here from the current technology with the radars that presently exist.

Now these are the aircraft that are used, the NOAA aircraft, the Department of Commerce here. We have two of those which are research aircraft, and they basically develop a new technology which we then transfer over to the Air Force C–130s and then use that operationally. You see a C–130 in the background there. NOAA has only two P–3s. The Air Forces uses 10 to 11 C–130s.

As the aircraft was flying into the storm, as it was now moving across the coast near Charleston, this is what we got back at the Hurricane Center minus the digitized radar there. Again, that is something we will get next year hopefully. The windfield is there. We were measuring about 140 mile per hour winds to 150 mile per hour winds at flight level, but at the surface we were estimating 135 mile per hour winds.

There is, again, the GOES satellite at the time that the eye was over Charleston with sustained winds of 135 mile per hour probably gusting up to 150 miles per hour.

Now, if we chose any place on the east coast for that hurricane to go in and say we are going to take that hurricane, go in somewhere on the east coast, and said where can it go in and give the least amount of damage, surprisingly it is right there.

You will see the big green zone up there which is the Francis Marion National Forest. Because the hurricane is much stronger on its right side—that is, to the north and east here of the center of the hurricane as it went inland—that is where the peak event is. That is where the strongest wind is, and that is where the largest storm surge is located. There are very few people over there.

I will show you a slide as to what it looked like over there, and you could imagine what it would have looked like on some of the other Barrier Islands or even in Charleston had the center of that storm been 20 miles farther to the south.

I think, Mr. Chairman, you indicated something like $5 billion roughly——

Senator GORE. $5.5 billion.

Dr. SHEETS. The last estimates that I have heard are now up to around $8.6 billion. I understand the insurance industry itself has had a loss somewhere close to $4 billion. Our statistics in the past indicate that the actual losses are two to three times that, so I would not be surprised to see that the bottom line when all of this is over is close to $8 to $10 billion. So it is a huge loss, and——

Senator GORE. Now, I do not think that figure has been used anywhere before. Do you think based on past experience and the new estimates that you have received that the damage from Hugo may be as high as $8 to $10 billion?

Dr. SHEETS. That is correct. What we have seen in the past as we looked at Alicia and all the past hurricanes, whatever the insurance industry has had insured, total losses are normally two to three times that. The insured losses as I understand it are getting close to $4 billion. It is roughly that. I understand State Farm had over $.5 billion itself.

So that is the total that I have heard, and if that is true, when it all gets done I would not be surprised if those estimates are out. I think it was the Charlotte newspaper that came up with $8.6 billion as their estimate this time, and I do not think that is unreasonable. I will illustrate that here in a moment.

I have looked at the wakes of hurricanes for many years, and I can tell you that I have never seen the massive damage that I have seen associated with Hurricane Hugo. I have seen more complete damage over smaller areas, but never over such wide areas.

My point here is the peak even was up there in the Francis Marion National Forest, and that is what it looked like, and you see the houses up there, and you see the trees are all gone. That is where the strongest winds were. That is where the highest storm surge was and, fortunately, there were very few people up there, very few houses, and so if that had hit a major metropolitan area, we would be looking at much more massive losses than we are in this particular case.

The storm surge up there got around 20 feet. You see up there it is around 20 feet, and right up there by that little upper right orange triangle is a little town called McClellanville just to the north of the peak event there, and up there they have one of those fishing fleets also, Senator Stevens. This is one of the fishing fleet areas up there.

And the captain of this vessel that is in the middle right there—it is the Patricia Ann—was there when I was doing this survey about two days after the hurricane or day after the hurricane, and he told me he stayed on board his vessel during the hurricane, and you see the water level down over on the left there. There used to be a two-story building between where those vessels are there and this water over there, and he said he cleared the top of that two-story building. It was still intact, and he cleared that, indeed, without touching the building itself.

Now, I cannot verify that the building was standing two stories tall at that stage, but certainly the storm surge was roughly 20 feet based on other measurements we had, and so he could have cleared that with the waves. We know that all of these ships are deposited on the land side where that building used to be.

Before the hurricane, we have all of these barrier islands where they are eroding away. They are actually moving. They go through a natural process of moving. And you see the little L-shaped building back there in the second row of buildings back there, the houses.

Before Hurricane Hugo on Folly Beach and this is after. There is the L-shaped building over on the left side. You see the whole front row is gone. There are none of those houses there at all, and you will notice down below there is that plastic, the black plastic that has been embedded in this means to protect your beaches.

And you have probably seen a lot of advertisements, but one of the famous oil companies who says put this behind your barrier there, and you now have a hurricane-proof barrier. And that is on national television, been used many times and touted as a way to protect your beaches. Put that plastic behind that, and you see that you save that. Well, that is the plastic down there, and I would like to take some samples and give to that oil company to show them the problems there.

And not only does the power of this storm surge illustrated by those houses that we destroyed, but you went into the second row of houses, and notice where those rocks are that used to protect it out there a few hundred feet out in front. They were deposited in this living room. Of course, the whole front wall is gone and moved right on into the living room with the furniture. It gives you some idea of the power of that storm surge.

A few years ago the island actually extended beyond this complex. It is called the Atlantic House, and you see the people playing volleyball back there. But as the erosion has taken place, the beach has eroded behind that. They just built up and have a very large kind of complex here. It is a commercial complex, and this is what it looked like before, and this is what it looked like after Hugo. Those are the pilings down below where the volleyball area is up there on the right side, and then the debris as you go in from there.

And up and down the coast. This is over on Sullivans Island. It is one of those barrier islands. You see the marshlands, the wetlands behind there. You see the large house that is over there. It used to be up front right here. In the back there you see a peak of a house that is on the left of the one that is standing. Well, that used to be the same kind of building. In other words, the whole first floor is gone, and that is just the second and third floor that is left over there on the ground.

You can see many and many of these up and down the coast. Before and after. All those buildings are gone and again, how we try to protect our beach areas and what happened is erosion takes place. You protect your area.

You notice that digs back in here on the left side, and so that is the kind of damage. Notice the brown roofed house on the center there, but see the two little houses over on the far right there and the protection they have had before the hurricane, and here is what they looked like afterwards.

And then back again, the brown roofed house in the middle, and look at the houses on the left before and after. See the brown roofed house over here.

And so you just go up and down there. A little house over on the lower left, the houses back behind and across the street there, the two back behind. Well, there is only one back behind, and it is not very good either at this stage.

And places where it actually made cuts through the islands. I got a letter the other day from a real estate salesman from down in South Padre Island because during the Barrier Islands Act testimony here, I had testified that there were cuts made through the South Padre Island which later were having buildings built in them. I actually said Padre Island. It is South Padre Island, and during Hurricane Celia we had a cut made through that island and later we have pictures which show that exactly where that cut is is a large condominium complex.

And I will suggest that when the sand fills back in here, that we will now see a house go right back into that cut again if the builder is able to do that. Some places this is all that was left. It was not connected anywhere. I have been doing a lot of driving out there, and I was looking for facilities, but this was not one of them.

You can see the washer and drier up there, but there were places that looked just like that, and that is all that was left. There used to be houses out there, before and after.

And again, going inland, the wind damage, you have got the storm surge and wind damage down here. We elevate because of the flood insurance programs, and then because of that we do not go properly above that, then they fail because of the wind. And you just see row after row after row of houses there, and so when we talk about the great tragedies that have occurred in San Francisco with the earthquake there and a number of buildings that have gone down there—and certainly those are tragedies, let us not forget the people in South Carolina and what happened up there because there many, many more houses up there and a greater population that was affected there. Not a whole lot of privacy left in those two bedrooms on the left side.

This is inland. Condominiums, houses right down on the coast, and you see that the house stood, but if you look up close, you see they have got some real problems down below. It is probably going to have to be destroyed.

This house here, condominium complex, corners. This is all the way up to Myrtle Beach. They had a renourished beach up. They lost all of that renourished beach plus an additional eight feet, plus the first floors of most of their hotels. This is inside the Holiday Inn, a very large complex up there at Myrtle Beach, and this is the first floor kind of thing you have seen all the way up through the Myrtle Beach area. Over 100 miles there.

I took this sign that says, "Help, please stay off the sand dunes." And indeed, we need to do that, but you notice the building back there did not do that.

However, one of your colleagues—this is the home of one of your colleagues, and he indeed built behind the sand dunes. He suffered a little bit of damage. This, I believe, is Senator Hollings' home.

Senator GORE. I have been in that home, and it is indeed beautiful. After Hugo, Senator Hollings has told many of us, they went around and checked. Because the house was safely behind the dunes, it survived without serious structural damage. At least, that was the first estimate. But a home—as I remember him telling the story—a home just in front of his that was not protected by the dunes was practically obliterated.

Dr. SHEETS. That is exactly right. He did the right things. He put shutters up, he built behind the sand dunes. He did have some glass breakage, and you see—and the wall there on the deck up there, it went out, so there is a little bit of damage there, and there was some roof damage and some other things there, but his neighbor suffered much more who built out next to the water.

So, you can build down in those areas and, of course, problems like this, these vehicles are not going anywhere. And if you were on Sullivans Island or the Isle of Palms or the Wild Dunes area—that is the Wild Dunes area where Senator Hollings is located—you were not going anywhere because this was the bridge that went to that island. In fact, it took about two to three weeks to get that bridge back in place there.

And our concern is that this may happen sometime before the people get off the island, and then they get trapped in that situation.

Now, the hurricane does not stop at the coast. It moves right on in, and here is where our new Doppler radars will do a lot better because we did not do all that well in our forecast as we moved inland. We did fairly well, but we underestimated the winds that were going to be impacting the Charlotte, North Carolina, as it moved in, and we really do not have much information as you go in because even with the density of observations there, they cannot describe these smaller scale features that Dr. Friday was talking about that the new Doppler radars will be able to define for us.

And, of course, there are tornados. This is actually in the wake of Hurricane Gilbert over Texas, where we had about 36 tornados as we go in.

And then, of course, we get the inland flooding and major damage from that as we go on in. Our concern along the coast is things like this. This happens to be in the Texas area, and the population changes that have taken place in the coastal counties of Texas from 1900 to 1985, and you can see they are growing rapidly.

In Florida we have nearly nine million people in the coastal counties now, and up here in Virginia, Maryland, Delaware, New Jersey, similar kinds of things. These are the permanent populations. If you talk about the populations there on weekends and during special holidays and so on, obviously they double to triple. If you go over here to the beach areas, you will notice that is the case.

And so far we have been fortunate that with the large population increases that we are seeing there on the left side of this diagram, we have the loss of property, and we have been going through a little lull period in hurricane activity in 1980 through 1987 or so, 1985, 1986, 1988 and so on, we have increased, and so now if we put Hugo on there, our numbers go off the top of the scale on the right. So, we have been seeing the losses increased markedly.

However, on the right side we are seeing the loss of life, and we have been able to prevent that and reduce that. Indeed, I think that you will probably not find a disaster like Hurricane Hugo that has caused roughly $5 to $10 billion worth of damage and the loss of life was kept to the amount that it is.

One life is too many, but to have that great a damage and be able to reduce the loss of life to the order of 30 over the continental United States, I think it is quite a feat, and that, I believe, concludes my testimony. Thank you.

Senator GORE. Thank you very much.

Let me say, Dr. Sheets, on behalf of all of those Americans who watched your reports during Hurricane Hugo, congratulations on a job well done. You were really excellent. You inspired confidence and enabled local officials to bring down the number of lives lost.

Indeed, it is ironic that as the number of lives lost goes down, the amount of property damage goes up. We as a Nation have to translate the warnings that you give us about hurricanes not only into measures enabling individuals to leave the area of greatest danger but also measures to prevent the destruction of condominiums and streams cut through the islands by hurricanes. We must begin reducing that property damage the way we have reduced the loss of life.

Let me ask some questions about the ability to predict these weather events.

First of all, let me say we may have a vote soon. If we do, we will recess briefly and come back.

Dr. Knauss, after the first round I want to give you notice that I want to ask a couple of questions about your trip to Noordvijk coming up. As I understand, you are one of four people who will comprise the U.S. delegation to the Dutch conference on climate change, correct?

Dr. KNAUSS. I think I may be one of eight, but yes, I will be one of them.

Senator GORE. My information is you have been asked to attend along with Dr. Bromley, Mr. Reilly and Dr. Bernthal. After we deal with this matter, I want to ask you a few questions on that.

Now Senator Stevens began his statement with a very powerful presentation of why it is wrong to close these weather stations. I want to pursue that and note that last spring Secretary Mosbacher announced that no weather stations would be closed until the modernization program was complete. Now that reassured some people in my state and maybe some people elsewhere.

At the same time, the Director of the Office of Management and Budget, Mr. Darman, announced that the money to keep the stations open would have to come from cutting the rest of NOAA's budget.

Am I stating that correctly, Dr. Knauss?

Dr. **Knauss**. That is essentially correct. We had to find the money to keep the stations open.

Senator **Gore**. What did you cut to keep the stations open?

Dr. **Knauss**. Those decisions were made before I got there, but we took cuts all across the board, including the ocean programs as well as some of the weather programs. So it was not just a cut within the National Weather Service. We had to cut coastal charting programs and a variety of programs.

NOAA, as you well know, operates a large number of activities, so the cuts were taken a bit here and a bit there to find the money.

Senator **Gore**. With all the discussion of Mission to Planet Earth to understand global climate change, we are not doing so hot on mission to the United States of America to monitor weather and climate here.

In 1979 the Department of Commerce and NOAA were responsible for about 45 percent of the Federal budget for weather forecasting operations and research. Over the last ten years, that percentage has been reduced steadily from 45 percent to 21 percent.

Is the Department of Commerce trying to get out of the weather forecasting business? That is the direction in which you are headed. How do you explain that trend?

Dr. **Knauss**. Certainly the Department of Commerce and NOAA in particular is not trying to get out of the weather service business. We are the National Weather Service. We do take our responsibility seriously. Our program for the modernization of the Weather Service I hope is some indication of the fact that we are attempting to do so.

It has been a difficult budget time for this administration, for this country and, as you well know, for the Federal Government in whole. We have had to take cuts. I would like to believe that the weather services we are providing because of satellites and things of this nature, the kind of things that Bob Sheets just talked about, although we have indeed taken cuts in our budget, there has not been a significant decrease in the quality of the weather service we have provided.

I will be frank with you. I would prefer, as I am sure lots of other parts of the Federal Government would prefer, to have more funds in my budget, but I am comfortable with the fact that we are continuing to provide service and that with our modernization program we are going to be able to provide much better service, sir.

Senator **Gore**. The overall budget dilemma facing the Nation is surely not your responsibility. As we evaluate assertions by the administration that no significant changes are needed—I know I am oversimplifying the position—and as we evaluate the implications of level funding for NOAA, when the extra expense of keeping the weather stations open has to come out of the NOAA budget, we need candor from you and from your colleagues about what the actual damage is going to be.

At some point, loyalty to the administration and an understandable desire to be a part of the game plan has to be superseded by a mandate to be candid with the Congress about what is going on.

What is the current administration position on the funding issue? Can we realistically expect to maintain current services and pay for expensive new technology without providing major budget increases to NOAA?

Dr. **Knauss**. Senator, I was just checking with Joe Friday. Statistics never lie, of course, but one of the reasons why the percentage decrease in the NOAA budget has gone down as much as you point out is because of the fact that satellites are now an important part of the Weather Service program. Many of those satellites are carried in the NASA budget.

Satellites, as you well know, are not cheap.

Senator **Gore**. So the overall total against which your percentage is measured has gone up?

Dr. **Knauss**. It has gone up considerably, yes, sir.

Senator **Gore**. But you have been facing pretty stringent fiscal cuts, right?

Dr. **Knauss**. There is no question we have been facing cuts, and we have been facing at least level funding.

Senator **Gore**. Now there is a political furor about closing the weather stations. I am part of it, also. I want to keep them open, particularly the ones in Tennessee.

We will hear more about that later today.

That political furor, which is probably most intense in Alaska but which also exists in so many other states, was handled temporarily by the Secretary saying, Wait a minute. We are going to keep them all open. Do not worry about it. Then OMB comes in and says, "yes, we are going to keep them all open, all right, but we are going to take the money out of the rest of NOAA."

Now your current plan is to close the weather stations—is that right?

Dr. **Knauss**. Yes, sir. If we go forward with our plans, we will go from around 247 stations to about 115.

Senator **Gore**. Starting when?

Dr. **Knauss**. Starting in 1993.

Senator **Gore**. Do you appreciate the impact that has on airline safety and on the ability of cities to have continued safe airline service?

Dr. **Knauss**. Senator, I believe Mr. Friday can do this with much greater detail than I, but the whole point of this modernization system is, indeed, to provide better services. We guarantee that there will not be less service in any one location.

We have asked for an independent study by the National Academy of Engineering, and if we cannot provide that, we will not close the stations. That is our bottom line, sir, and we are presenting this to you in these implementation plans in a rolling three-year plan where we will show what it is we are planning to do and how we are going to do it.

Senator **Gore**. Now when is that plan coming?

Dr. **Knauss**. The first plan will be this fiscal year, and it is now presently in its final stage of being put together in the Department of Commerce.

When do you expect it to be ready?

Dr. **Friday**. I would expect it to be ready within the next few weeks.

Senator **Gore**. It took almost a decade to complete the strategic plan for weather service modernization, did it not?

Dr. **Friday**. That may be a little bit of an exaggeration, but it took a long time.

Senator **Gore**. All right. I am reading from the material that was prepared for the hearing here. There is also a legislative mandate in P.L. 100-685 to get the implementation plan released, correct?

Dr. **Friday**. That is correct.

Senator **Gore**. That legal requirement is the reason why it is supposed to be submitted at the beginning of the fiscal year, correct?

Dr. **Friday**. It is supposed to be submitted in association with each fiscal year.

Senator **Gore**. You have missed that deadline, have you not?

Dr. **Friday**. Yes, sir.

Senator **Gore**. The next few weeks, is that a reliable estimate?

Dr. **Friday**. Yes.

Senator **Gore**. Let me ask this question, Dr. Sheets, on behalf of Senator Hollings. You were in the air less than 36 hours after the hurricane landfall doing an initial damage assessment, were you not?

Dr. **Sheets**. And on the ground.

Senator **Gore**. Was not the full extent of the destruction apparent at that time? When did you first revise your understanding of how severe the destruction was?

Dr. **Sheets**. There were several of the media with me as I was going around. They intercepted me wherever I was. And, indeed, we were talking about the fact that it was a very massive kind of destruction that had taken place there, so I suspect that would be Saturday evening when the hurricane struck on Thursday night and Friday morning that we were there first thing Saturday morning, and so it would be Saturday evening.

So, yes, about 36 hours.

Senator **Gore**. I will come back to this after the vote, but let me just say that in the aftermath of the hurricane, one of the primary excuses given for the delay in relief operations was that the administration said it did not comprehend the full extent of the damage. I think that Senator Hollings has noted that may not be entirely accurate.

When we come back, I will recognize my colleagues, and we will come back to it on a second round. We are going to have a brief recess for the vote, and we will crank it back up in about eight or nine minutes.

[Recess.]

Senator **Gore**. The hearing will come back to order.

While my colleagues are returning from the vote, Dr. Knauss, let me ask you a couple of questions about the climate change issues that will be discussed in Noordwijk.

The delegation from the United States will include you, Allan Bromley, Bill Reilly from EPA, and Dr. Bernthal from the State Department. Has the U.S. position been formulated yet?

Dr. **Knauss**. I think the U.S. position is being formulated. There will be a further meeting on the subject on Monday, to my understanding.

Senator **Gore**. There will be a further meeting?

Dr. **Knauss**. That is my understanding.

Senator GORE. And as yet the final position has not been formulated. Is that correct?

Dr. KNAUSS. That is my understanding.

Senator GORE. Do you believe that the level of understanding we currently have about global climate change warrants changes in the activities of industrial civilization?

Dr. KNAUSS. I certainly think the level of understanding we have of global change at present requires that this nation and all other nations give very serious consideration to that particular subject, and I believe it is imperative upon the United States to begin that which it has not yet done to think through the implications of those changes and what they will mean.

Senator GORE. So, you think we should consider them, but you think it is premature to actually make some changes?

Dr. KNAUSS. I am a very conservative person, Senator, in the sense that I would like to at least work through what the implications are of those changes before I make the changes. I am not talking about five years or ten years. I am talking about essentially a process that we should start right now to consider and work through what we should be doing, what the implications are.

I think my disagreement with perhaps statements I have heard you make is not the question of whether we should do anything, but the timing of when we should do it.

Senator GORE. You would prefer to wait until later?

Dr. KNAUSS. I would prefer to wait.

Senator GORE. You think there is still too much uncertainty to justify some actions now?

Dr. KNAUSS. My sense is that there is enough uncertainty with respect to our understanding of global climate change, and you know what those uncertainties are as well as I do because I know you have studied this problem.

I do think that the probability of global change or global warming, if you will, because of greenhouse gases and so forth is probably quite high, and I do think, therefore, a prudent person or prudent nation would begin to take action or begin to consider action, at least.

Senator GORE. Wait a minute there. That "or" there is an important one. A prudent nation would begin to take action or consider taking action. Which side of that "or" do you come down on?

Dr. KNAUSS. I come down on consider taking action.

Senator GORE. In your opinion, it is really too early to take action to do anything about it?

Dr. KNAUSS. No, sir. If we had started three years ago and worked through the economic implications, the policy implications of what action would mean to this nation and to this world, then I would say perhaps we should be taking this action now. We have not done that in this country so far as I can see.

Senator GORE. I started nine years ago calling for exactly that, and the administration and its predecessor, of which President Bush was a prominent part, resisted even that.

But just to make it a little clearer, you said there is a high probability of harmful global climate change coming from the pattern of industrial civilization and its impact on the environment, correct?

Dr. KNAUSS. I believe there is a high probability based upon president evidence, based upon geologic evidence of what has happened in the past, and you have raised CO_2, that we will have an anthropogenic-driven, manmade effect which will be superimposed upon the random variations that we know we have with or without man.

Senator GORE. Would you say that number quantifying high probability is closer to 50 percent or 90 percent?

Dr. KNAUSS. I put it at about two-thirds.

Senator GORE. You put it around 66.6 percent?

Dr. KNAUSS. About two-thirds.

Senator GORE. So, you think there is a 66 percent probability or a 67 percent probability of harmful global climate change caused by human civilization?

Dr. KNAUSS. I would say there are those who are not convinced that it is harmful. There is going to be a global change.

Senator GORE. What about you? Are you convinced? Let us say we do get a warming of five degrees centigrade. Do you think that would be harmful to our civilization?

Dr. KNAUSS. I think it would cause great disruption to our civilization.

Senator GORE. You agree with that?

Dr. KNAUSS. Yes, sir.

Senator GORE. You think there is a 67 percent probability of that occurring?

Dr. KNAUSS. I think so.

Senator GORE. But it is still too early to do anything?

Dr. KNAUSS. No. You misunderstand me.

Senator GORE. I am trying to understand you, and I want to give you an opportunity to be understood. The government of the United States is right now in the midst of trying to be understood on this question. And the executive branch is having some difficulty being understood on this question. As a result, this meeting to which you referred will take place on Monday to try to clarify our position going into this conference so that we can be understood.

And the key point is in dispute—with the head of the EPA and the Secretary of State on one side, Dr. Bromley and Dr. Sununu on the other side, and you somewhere in the mix. The key questions are—Will we invite these other nations to come to the United States because President Bush has decided to be a part of a process to start doing something?

Will we agree with the other nations that come to Noordwijk to sign onto a plan of action, or will we take the position that we just do not know enough and really the only sensible response is more research?

So, which side of the questions do you come down on?

Dr. KNAUSS. I believe that more research is important. I would like to reduce that uncertainty by more than it is, and I think that the United States has a well thought through global research program, again, under the work under CES under Dr. Bromley's efforts.

My concern primarily, sir, is the question of—and the President has called for a framework convention. My only concern—and the protocol based on that will come after the framework convention.

The framework convention does not say anything, but then you have the protocols which will say we will either reduce CO_2 emissions or stabilize them or these kinds of things.

The economic implications to this country and to this world of stabilizing or reduction are profound. I would like this country at least to have thought through what the implications are, the economic implications are of making that decision before we go too far down the track of having a framework convention and then working on the protocols. And there is enough uncertainty with respect to the science that I believe it would be worthwhile to spend at least a year or about a year at least in trying to figure out what the economic implications are of the policies that some people have been suggesting.

Senator GORE. I am going to finish up this line of questioning very quickly in deference to my colleagues, but just a couple more.

You are familiar with the scientific view that if we wait, some of these changes may become irreversible. Are you familiar with that?

Dr. KNAUSS. I think some of the changes are irreversible already.

Senator GORE. Do you agree that more of them become irreversible with each passing year?

Dr. KNAUSS. You add a half a percent CO_2 each year. You add 1 percent methane each year.

Senator GORE. It is going up, actually. We used to add that percentage—we were adding one and a half parts per million each year. We are now adding two and a half parts per million the last two years.

Dr. KNAUSS. There is no question. The longer you wait, the more the problem.

Senator GORE. Are you familiar with the almost exact correspondence of the temperature record and the CO_2 levels in the atmosphere over the last 200,000 years?

Dr. KNAUSS. You mean looking at the ice cores? I have seen that data.

Senator GORE. Are you familiar with what the CO_2 loading of the atmosphere was during the last interglacial period, the warmest time?

Dr. KNAUSS. I do not remember the numbers, but I have seen the drafts.

Senator GORE. About 300 parts per million. Do you know what it is now?

Dr. KNAUSS. 340?

Senator GORE. No. The graphs that you are thinking about end at 349, but that was two years ago. Now it is about 354 parts per million, and it is still going up two and a half parts per million each year. How high do you think that it should go before we do something?

Dr. KNAUSS. If this country had worked through what the policy implications are, the economic implications are, of essentially making a—look, Senator, let me put it to you this way. If this country is prepared to go nuclear power 80 percent, like France is, then I would say we could do it right now. I do not think this country is prepared to do that.

Senator **Gore**. With all due respect, I think that is an infrared herring. We do not have to agree with those who want to go whole hog on nuclear power right now.

I personally believe that nuclear power is going to play a role in this, but this problem is not going to be solved unless we approach it on a global basis—unless we in the United States are willing to make changes in the area of efficiency, conservation, mileage standards, et cetera. Here we have the little nation of Holland filling the vacuum left by the United States because the Administration cannot decide to do anything on it.

You are one of our delegates there——

Dr. **Knauss**. Senator, if what you mean by doing something now means increasing the efficiency of our automobiles and increasing the efficiency of our electrical engines, I think we should do that for other reasons quite independent.

Senator **Gore**. There are a lot of things we should do for other reasons anyway, but we cannot get the Administration to agree to those, either—most of them.

But on the question that you will be facing this coming Monday, I just want to say before I conclude my part of this that we are going to have Dr. Bromley here tomorrow in a hearing with his appointee for the part of OSTP that handles a big chunk of global climate change. We are going to pursue it with him as well.

I have a lot of respect for you. And do not take this wrong, but I am deeply disappointed in the Administration's refusal to allow Mr. Reilly, the head of our EPA, to go to Noordwijk with a meaningful position, the refusal to allow him to fulfill President Bush's campaign promise to invite the nations of the world to come here and talk about doing something to combat global climate change.

Of course there are economic implications. There are also ecological implications of doing nothing. We are witnessing the loss of living species at a rate 1,000 times greater than at any point in the last 65 million years.

We are seeing increases in global population that are unprecedented. It took 10,000 lifetimes to reach 2 billion, and now in one lifetime we are going from 2 billion to 10 billion. And we cannot decide to do anything about that, either.

Let me just conclude by saying I hope that in the meeting on Monday that you will reconsider your view that it is not time to start doing something about global climate change. I hope that Mr. Reilly and Secretary Baker will prevail in their arguments that the United States ought to go to that conference in Holland with a meaningful position. I hope that the United States will not be embarrassed by coming off as a foot dragger, saying that we simply need more research on global climate change before we actually commit ourselves to doing anything about it.

I will give you a chance to respond, then I will recognize Senator Stevens.

Dr. **Knauss**. I have nothing more to say.

Senator **Gore**. Senator Stevens?

Senator **Stevens**. Thank you. I understand Dr. Knauss has another engagement.

Dr. **Knauss**. I have an airplane to catch. I will have plenty of time to make it, unless there are three more votes.

Senator **Stevens**. Let me start off by saying this. It is my understanding that current law says the Secretary cannot implement this modernization plan unless he certifies that modernization will not result in the degradation of services to the general public.

My first question is, is that on a national average, or are we going to do it state by state, or area by area? What is your interpretation of that?

Dr. **Knauss**. My interpretation is that it is done area by area, sir.

Senator **Stevens**. That is one mark on the wall. I want you to know I have looked at this plan and it appears that the plan has concepts of modernization which relate very strongly to what we call the lower 48 but it sort of looks like people just did not quite know what to do with Alaska. I do not know whether that is fair or not, but that is the implication.

We have 17 weather service offices, we have three of the current forecast offices. The forecast offices were consolidated some time ago, so this plan consolidates all the 17 offices into the three forecast offices, so there would be three locations in Alaska, one fifth the size of the United States. Is that proposed action subject to any review under this plan?

Dr. **Knauss**. Yes, sir, it is subject to review under this plan, but let me ask Dr. Friday to perhaps talk a little bit more about the details of the Alaskan plan.

Senator **Stevens**. Thank you, Dr. Friday.

Dr. **Friday**. Thank you, sir. The Alaska plan calls for three offices, Anchorage, Fairbanks and Juneau, which would be fully staffed with forecasters on a 24-hour-a-day basis providing support for the State of Alaska.

It is much the same organizational structure as we have now, with those three offices providing all of the forecasts for aviation and the like for the entire state.

In the present office structure in Alaska, as you point out, we have the weather service offices ranging from Barrow to St. Paul and down to Annette Island. Most of those offices would still be there taking data, taking the upper air observations that are so vital, and monitoring the equipment and so on.

They would not be operating 24 hours a day, they would only be operating probably 14 to 16 hours a day, and they would not be providing any services to the public at that point. They would simply be a reduced staff for the purpose of taking weather observations.

Senator **Stevens**. That is what I want to get to. As I understand, there are about 50 forecast offices in the south 48 now, and after this plan is through they are going to be increased to 112. These are the most expensive portions of your whole system, are they not?

Dr. **Friday**. Yes.

Senator **Stevens**. You are doubling the expensive ones. It is my understanding, for instance, that Texas is going to have ten such offices. You are going to, as I said, double up on those in the lower 48, but we remain static. What do you do with the service offices in the south 48?

Dr. **Friday**. Approximately 100 to 115 of the weather service offices in the lower 48 will eventually be closed.

Senator **Stevens**. They in fact have upgraded many of them to forecast offices, have they not?

Dr. **Friday**. 65 of those offices will be upgraded to forecast office. The weather forecast office in the strategic plan and the weather service forecast office in the present organizational structure have some slightly different characteristics.

The WFOs in the strategic plan are in general smaller than the forecast offices are at present, and they have a smaller area of responsibility.

Senator **Stevens**. You said small-scale features drive local weather events. In terms of the service offices in Alaska, I am told that they forecast regional weather on a 12-hour basis, take into account local weather conditions, they collect meteorological data to relay to the forecast offices, and their major function is addressing the service needs of local citizens.

That means they not only deal with the forecastings, they brief pilots and fishermen and people that are interested and must have weather data, they have two-way VHF radio for weather information on a real-time basis, and they also have the NOAA radio broadcasts on the local stations for current weather conditions on a quite frequent basis, and particularly in the various fishing seasons. That is around-the-clock.

I am sure you realize that our people in the summer time fish literally around the clock. It is 24-hour sunshine.

Now, all of those will be discontinued, right? All of the service functions of the service stations will be discontinued?

Dr. **Friday**. The services that are currently being delivered to Alaska, including the NOAA weather radio, including the radio broadcasts to the fishing fleets, all of those functions will be continued from the restructured office complement in Alaska.

Senator **Stevens**. Respectfully, now, how could someone in Anchorage go on a daily—not daily, but five times daily radio station in Dutch Harbor that does not reach any other community in the state, other than just the fishing industry around there? How can you have that availability?

Dr. **Friday**. The specific cases you point out, I am not sure exactly what arrangements are being made there. The Kodiak broadcast that Peggy Dyson does at the present time will be supported for her out of the Anchorage office. The Anchorage office will actually be increased as far as capability for marine weather support throughout the Gulf of Alaska and take on major responsibilities for that.

Senator **Stevens**. I want you to know what worries us is, the flight service stations are also being automated, you understand, and now you have the comfort of knowing that the person that is telling you that you are clear to land in Holikachuk is sitting in Anchorage, two mountain ranges away.

Now we are going to have the fellow that tells us it is all right to land if you have got a 1,000 clearance, or ceiling there is also two mountain ranges and 1,500 miles away. You know, are you going to feel really comfortable? If you want to look at the south 48, that is the difference from St. Louis to San Francisco. Are you going to tell the people in San Francisco you are clear to land sitting in St. Louis?

Dr. **Friday**. My predecessor in the National Weather Service was from Pennsylvania and my home state is more or less Oklahoma. Every time I visit Alaska, our Alaska regional director always shows a map.

They showed for Dr. Halgren a map of Alaska with Pennsylvania lying between all the observation points. They now show a map with Oklahoma lying between the closest observation points, so I understand that.

I would point out, as a part of the modernization in Alaska we have over 100 additional surface observing systems going in across the state, automated surface observing systems.

We have been testing them out in the Arctic area now with Fairbanks for the last three years, so that we will have much better observational coverage to provide that kind of data for whoever is providing the service, whether it be located at the present time in Nome or in the future in Fairbanks.

Senator **Stevens**. Well, you know I am reminded that our friend—we all feel he is a friend, because we saw him so much recently—Dr. Sheets is sitting there with you. We have more earthquakes, more floods, more storms—now, not up to the size of Hugo, but more storms, as I understand, in the State of Alaska, than all the rest of the country put together on an annual basis.

Now, what you are saying is that the people out in the Aleutian chain can feel secure because their weather station is in Anchorage. What happens if they have another earthquake in Anchorage, or Fairbanks, or southeast? You are putting everything in one place.

But beyond that, you also tell us that we have got these new radars, the NEXRADs. I am told that those, in terms of Alaska, although there will be seven of them, will only cover 10 percent of the area of the state. Is that right?

Dr. **Friday**. That is approximately correct, although we are concentrating their coverage on the area that is most weather significant, along the Gulf of Alaska, in the southern Bering Sea and so on.

Senator **Stevens**. But they do not go over mountain ranges.

Dr. **Friday**. No, they do not.

Senator **Stevens**. So that my son, in his vessel that operates out of Dutch Harbor, if he is on the other side of the Aleutian chain from the one that is going to be located on St. Paul, he is not going to get any assistance out of that, is he?

Dr. **Friday**. Not from that radar, no, sir.

Senator **Stevens**. And the people that operate down in Valdez, down around the Prince William Sound, are not going to get any help at all from this new Doppler radar.

Dr. **Friday**. There is a radar planned for the Valdez area.

Senator **Stevens**. It does not go over mountains. It goes about 20 miles and stops. I have real trouble with the modernization concept as applied to Alaska. I really want to try and see what the schedule is.

Let us just take Valdez. God knows, we do not want to see another incident like we have had this year, and yet I am told that there is a tailored forecast coming out of Valdez right now, for tankers, that they do have to have precise information before they come into the Valdez arm, and that under the plan that is involved here, the Doppler radar will not provide them the assistance that they should have, that you will be going from a manned service station to an automated one.

What is the plan? Have you gotten specifics to deal with the tanker traffic? It is the largest movement of oil in the United States, 2 million barrels a day coming out of that Valdez arm.

Dr. **Friday**. The current operation in the Valdez harbor area, through the Coast Guard, with support of weather information for the tanker operations. That is certainly the case.

The future plans call for that support to still be provided to the Coast Guard, to the harbor master and so on, for the operation in that area, and to be provided for support out of the Anchorage office with all the capabilities, then, of the satellite coverage over that area and with all the radar coverage that we have in that area for what purpose it might serve.

Senator **Stevens**. Respectfully, it is like dealing with giving Seattle, Puget Sound, traffic control out of Denver. And I just do not quite understand that. I do not think you can do it over mountain ranges and in areas that have fjords, like Norway.

And I really believe that someone ought to get very specific about some of the plans. What about the airport at Valdez? Where does it get its——

Dr. **Friday**. The airport at Valdez is currently provided operational observations by the FAA at their flight service station. The forecast there——

Senator **Stevens**. Which has been, by the way, automated. It is coming from Anchorage, too.

Dr. **Friday**. And the forecast for the Valdez airport is now and has been coming from Anchorage all along. It has been disseminated, it has been relayed from the office in Valdez.

Senator **Stevens**. Well, I understand the long-range forecast comes from Anchorage, but the daily observations and the hourly observations, when I go in there, we get up-to-the-minute as we come up the sound.

Dr. **Friday**. That is correct.

Senator **Stevens**. And if they do not say you have got the minimums, you turn around and go back. But we have had a forecast all the time that it might be open by the time we get there.

I am going to tell you, in terms of the problem that I have is this. You all are professionals, can you look at me now as the Senator for Alaska and say there is not going to be any degradation of service for Alaska under this modernization plan; that the local service, as well as the forecasting service, will be as good as it is now?

Dr. **Knauss**. Senator, I would like to think we can say that. But we are going to be routinely reviewing this program. And if, in the view of the professionals, we feel that we cannot make that statement to you, we will make the changes, sir.

Senator **Stevens**. All right. I have one last question, and I have overstayed my leave, too. Your system, as it applies to the whole country now, is sensitive to the availability of energy, you know, electricity, for the service kind of support you need in concentrated areas.

Our earthquake in 1964 was 150 times the magnitude of the recent one in San Francisco. It destroyed communities in an area of a circle of at least 750 miles from the epicenter.

Now, what are we to do for the rest of the state if the supports for your service are in any one of those areas? It will be out for a substantial period of time.

Are we not better off in this country as a whole, and particularly in areas like mine, in having more discreet centers that are dispersed, than to go to the concept of having one large forecast service center in the metropolitan areas of the country?

That is what it looks like your plan does. It moves them all into the cities. We are coming in from 17 locations into the three major cities of Alaska. And as I look at the south 48, except for Texas, it appears to be the same thing.

Is that a plan we ought to look at as being modernization, to commit us to a concept of maintaining the existing level of public service?

Dr. FRIDAY. Sir, it is impossible to design a zero-risk option, as far as any natural disaster as you have described.

With respect to the office structure that we have proposed for the lower 48, as you have just addressed, we started essentially taking a look at the reasonable area of coverage with the type of weather, the type of equipment and so forth that would be available in the lower 48, and we did concentrate on our existing office structure. We tried to stay where we were already located in these major cities. There is no question about that.

The system itself is robustly designed to take care of damage to any one of the centers or any one of the nodes. The system is designed, the communications structure, the forecast structure and so on, so that if one of the cities goes down, if for some reason we have a catastrophic failure of one of our weather forecast offices at a particular location, or indeed one of our radars, or something along those lines, then the surrounding offices will take over the responsibility for that area.

It certainly will not be as good as if we had the existing structure, but certainly is something that we have planned for, second and third-level backup, during this time.

We are as concerned about operating in a harsh environment as anyone. We have to have the weather forecast offices capable of operating in bad weather, otherwise they do little good. We have emergency power available for all of the new offices, we have backup communications facilities available, all planned into the system, and, as I indicated, second-level backup arranged.

I would be less than candid if I told you that I was sanguine about all aspects of the Weather Service. We are beginning the most significant change of the Weather Service in its 120-some-odd year history, there is no question about that: the way we handle the technologies, the way we have the trained people, the way we deliver services, the number of offices that we have, and so on.

There are ways throughout this entire thing, there are options throughout this entire program that we have undertaken to fail.

You asked if I could look at you and tell you that I felt that the plan that we had was a good one. I can tell you this, sir, at this stage of the game, quite honestly, this has been put together over many years—Senator Gore indicated a decade, not quite, but close—it has been put together with many discussions and many debates over the best way to provide warning and forecast services to this country in a cost-effective manner.

I believe at this time that the plan as we have proposed, and I agree with Dr. Knauss, we do need to relook at the exact options that we have, not only in Alaska, but also in Hawaii, and we will do that, but I believe the plan as proposed will indeed present better weather warning and forecast services to the population of this country.

I would quite frankly be unable to be here if I did not believe that.

We have a long way to go. And we do intend to live with the public law which says that we must prove that to you and to all of our constituents to make sure that we are not shortchanging the American public.

Senator STEVENS. Well, I wish we had more time. I would like to know, for instance, did someone give you a trend line on how much money would be available through the period of this plan?

Dr. FRIDAY. Yes, sir.

Senator STEVENS. So, it is really subject to economic constraints based on some assumptions of budget forecasters, right?

Dr. FRIDAY. Yes, sir.

Senator STEVENS. And I assume that is the current trend line?

Dr. FRIDAY. Yes.

Senator STEVENS. It does not show any massive increase or massive decrease?

Dr. FRIDAY. The investment in the modernization of the Weather Service is substantial. By the time we count in the new technologies for the satellites, the training and the education of the people, the instrumentation across the country, the facilities that are necessary and all of that, we are talking about numbers in excess of $1 billion to be spent over the next seven or eight years.

It is a major investment in being able to improve weather services to this country. The goal is to have a very effective weather service at the lowest practical operational cost. That is what we believe we have been able to do.

Senator STEVENS. I will not ask any more questions.

In walking over to the last vote I told Senator Gore that I am beginning to believe we have to have some new categories of priorities as far as the federal budget is concerned, and this would certainly be one of them. I cannot think of anything that is more significant to the health and safety and lifestyle of America as NOAA is.

And we sit here with some $6 billion to $8 billion in a trust fund that was paid by people who buy airline tickets and we cannot spend it because of budget restrictions. I believe a lot of those people who pay those taxes think a portion of that goes to support the weather predictions for access into the airport that they intend to land at.

The Weather Service is absolutely vital to the functioning of our transportation system. Eighty percent of our people moving from city to city now move by air. You tell them whether they can get there, whether they should take off or not.

I sat waiting 30 minutes last week on the end of the runway until they got a clearance from your people saying that they could in fact get into the destination airport.

The integration of your system with the aviation system is not complete. I do not see it in this plan either. And I think that one of the things we have to do is get the integration between the people that are paying for your service and those of us in the Congress who are supposed to be making it available to you so you can assure that it is there.

And I do not like the trend line in this budget. I do not think it is planning for the next century. It does seem to me that it is modernization, but it is modernization to meet the declining revenue base for NOAA, rather than an expanding demand base, as far as the American public is concerned, into the next century.

And so I really have to be critical of it. And I believe that it would not be possible for the secretary to certify that this plan would meet the needs of the people of the United States in the next century. It might meet them now, but I do not see any expansion capability here that would not be more costly because you, in fact, have rolled in your sidewalks and brought them into the metropolitan centers.

It must be cheaper to maintain your people in Anchorage and Fairbanks and Juneau than to have them in Unalakleet, Koliganek and Dutch Harbor. I do not doubt that at all. But the same thing exists throughout the country. We should have more access to weather information in more places, otherwise we are going to concentrate our travel in those big, major cities, too.

But the difference between us and everybody else—I will close with what I said at the beginning, if you do not get on a plane in Dallas and you wanted to go to Houston, you can drive; if you do not get on a plane leaving for Kodiak from Anchorage or Dutch Harbor or Koliganek, or Shishmaref or wherever the devil it is, except for Fairbanks, in Alaska, you cannot drive.

And if there is anyplace that is sensitive to your business, it is my state. And I do not think you could certify that this would comply with the Act.

Do you think, Dr. Friday, you could certify that this plan, put into place in Alaska today, would not reduce the services available to my people, who rely on weather data?

Dr. FRIDAY. After listening to your very persuasive statement, sir, I certainly will relook at the plan, as we have indicated.

Senator STEVENS. Thank you very much.

Thank you, Mr. Chairman.

Senator GORE. The problem extends to the satellite coverage.

How likely is it that we will go for a one- to two-year period without a GOES satellite?

Dr. KNAUSS. As you know, there is presently only one GOEs satellite because we lost one on launch. It is expected to continue to operate until we have the next one up, which at this point is spring of 1991.

Things can go wrong. We are going through a major solar flare sunspot cycle now. I was told we lost 4 percent of our energy with the present GOES just in the last week because of being hit by protons and other cosmic rays. It is very hard to predict a catastrophe, sir, but, absent a catastrophe, we will have a GOES satellite up continuously until the new one is up.

Senator **Gore**. I certainly hope so.

There was some discussion of borrowing the services of a Japanese satellite, was there not?

Dr. **Knauss**. We have various contingency plans, of course, for what would happen if we should lose our present GOES satellite.

Senator **Gore**. That is one of them?

Dr. **Knauss**. That is one of them.

Senator **Gore**. We are borrowing everything else from the Japanese.

Just briefly on the technology again, I understand there is a reliability problem that is of increasing concern for NEXRAD. Is it true that the present radar system has a demonstrated reliability ten times greater than what is turning out to be the case with NEXRAD?

Dr. **Friday**. This is another case of interesting statistics, Senator. The preprototype radar unit that was the subject of the test over the past few months at Norman, Oklahoma was, as I indicated, not a production radar. It was a breadboarded radar so that we could test the capabilities and identify deficiencies in the system as we move forward into production.

The reliability of that system was, indeed, low. Even with the reliability as low as it was, we ended up with the improvements in the accuracy of the warnings and forecast, as I indicated.

The first production unit has been under test now for the last three months at the factory in preparation for acceptance and delivery to the central Oklahoma site. There has been only one minor failure in that transmitter, that system now for the last two and a half months or so. So the reliability of the production system is quite high and is meeting the specifications.

I would point out that the reliability of the present radars in general is very high, but some of them are aging at such a rapid rate that we have been out of operation with some of our existing radars for up to two or three weeks because of major failures or parts problems and reliability problems as well.

Senator **Gore**. You have set aside in your own mind what your decision will be on full production, which is a decision that has to be made by January 31?

Dr. **Friday**. As a matter of fact, sir, my counterparts in FAA and the Air Force and I will be meeting tomorrow afternoon to review that recommendation. We will be reviewing the results of the interim activity since the test was completed in August. We will be reviewing the results of an independent team that has been looking at the method.

So we will be coming to those conclusions within the next few days.

Senator **Gore**. It is a tough judgment. We wish you well in making that.

Now the fruit frost warning program is cut out by the administration every year and put back in by the Congress every year. Does the modernization plan cut out the agricultural weather services like the fruit frost warning program?

Dr. **Friday**. Yes, sir, it does.

Senator GORE. Do we not need that?

Dr. KNAUSS. The position of the administration has been for some time that there is a role for privatization of some aspects of weather services providing value added forecast. It has been the view that is a role for private forecasters. Congress has disagreed.

Senator GORE. A final couple of questions here on Hugo, Dr. Sheets.

Do you agree with those who say warmer oceans mean more powerful hurricanes?

Dr. SHEETS. Theoretically, yes. We have seen no evidence of that. What we have seen in Hugo and Gilbert we can show you occurred in the 1940s, 1950s and 1960s. So what we are seeing now is a return to more normal hurricane activity.

Our memories go back only after the last two decades when we have been down in hurricane activity. What we have seen in these past hurricanes in my opinion has nothing to do with global warming.

Senator GORE. Do you have data on ocean temperatures over the last few years in the doldrums?

Dr. SHEETS. We watch that on a daily basis, as a matter of fact, during the hurricane season.

Senator GORE. What has been the trend this year?

Dr. SHEETS. No abnormalities at all. It is plus or minus one degree across the belt, and that occurs every year.

Senator GORE. Now if Hugo had hit south Florida, is there any way you could estimate what the damage would have been down there?

Dr. SHEETS. First, the building codes in southeast Florida are far superior, and the building practices are far superior than what were there in South Carolina. The newer codes that were applied up in South Carolina are similar to those in southeast Florida.

Had that building code practice been in effect along the South Carolina coast, I estimate that along the coast the damage would have been reduced maybe 30 to 40 percent just due to proper building. We have a much greater population density, however. For instance, we talked about massive damage over a width of more than 100 miles.

So if you were to bring that hurricane into, say, the Miami area, you would have massive damage from the Florida Keys up through almost the Cape area. So, indeed, the dollar damage would be in excess of $10 billion, in my estimation.

Senator GORE. Senator Gorton has questions for the record. Other Members of the committee may, as well. I hope that you will be willing to respond in writing to those questions.

[The following information was subsequently received for the record:]

**Answers to Questions from Senator Ernest F. Hollings
for the Record of the October 26, 1989 Hearing Before the
Senate Committee on Commerce, Science, and Transportation
on the National Weather Service**

Question 1:

Last year's NOAA atmosphere and satellite authorization bill (P.L. 100-685) requires that an annual implementation plan for Weather Service modernization be submitted to Congress at the beginning of the fiscal year. What is the status of that plan, and when can we expect to see it?

Answer:

The National Implementation Plan for the Modernization and Associated Restructuring of the National Weather Service required by Public Law 100-685 is currently under review within the Department of Commerce. The National Implementation Plan will be ready for submission to Congress early in 1990.

Question 2:

Testimony at the hearing outlines some of the current uncertainties regarding the range and capabilities of the new NEXRAD system. I understand that the coverage provided by a NEXRAD radar may be limited by local geography and conditions. This limitation has raised serious concerns for population centers which are located at the periphery of the range of planned units, for example the Upstate South Carolina area. How do you plan to evaluate the adequacy of coverage provided in such situations? Will additional radars be installed if the planned coverage proves to be inadequate?

Answer:

During operational tests of the NEXRAD prototype at Norman, Oklahoma from March through August 1989, excellent meteorological data were obtained throughout the Doppler performance range of 230 kilometers, or about 144 miles. During the trials, forecasting accuracy was significantly higher than the current national average (91% vs. 58%), while the false alarm rate was much lower (21% vs. 57%).

The enclosed chart indicates the areas of Doppler coverage which the planned NEXRAD installations in and around South Carolina will provide. Greenville and Spartanburg are well within range of the planned radar at Columbia. No area of upstate South Carolina lies beyond Doppler coverage from at least one network site.

This coverage evaluation reflects extensive on-site technical studies and computer-assisted laboratory analyses based upon the Defense Mapping Agency's terrain data base and NEXRAD's verified performance characteristics. The effects of local geography are accurately accounted for and depicted. Preliminary and in-depth site surveys for the Columbia NEXRAD were accomplished by SRI International and are documented in the enclosed reports.

The NEXRAD system and other components of NWS modernization, including advanced satellite and surface observing systems and faster, more powerful data processors, will be utilized to insure uniform and substantially improved weather detection throughout South Carolina. Public Law 100-685 stipulates that services will not be degraded due to the modernization.

Question 3:

There are a number of weather warning and forecast activities currently being carried out by the Federal Government that are not addressed in the modernization plan. Please explain what changes, if any, you expect in the following programs as a result of modernization: (a) the Air Force hurricane reconnaissance program; (b) the National Cooperative Observing Program; and (c) agricultural weather services programs.

Answer:

(a) We anticipate no change in the aircraft reconnaissance program.

(b) Data from the cooperative network are of two types: real-time and archived (non-real time). Under the modernization, there will be no change in non-real time data, which will continue to be recorded by the cooperative observers and mailed to the National Climatic Data Center at the end of each month. There will be a gradual increase in real time data in the Eastern and Western Regions as observers are equipped with devices such as Touch-Tone telephones, that will be used to transmit observations via telephone lines to computers. The Central and Southern Regions already are using various communications devices to send real time data.

(c) The National Weather Service's modernization plan does not address the Agriculture Weather Service Programs because this program is a Federal service that is more appropriately a private sector responsibility.

Question 4:

I understand that installation of the new weather observing systems will result in a flood of data to weather forecasters at the local level. For that reason, the information systems to integrate all this data (AWIPS) will be essential for making full use of the new equipment. However, in recent years, the

Administration has proposed to slash funding for AWIPS and at one point tried to drop the program altogether. The bottom line is that the AWIPS schedule is slipping further and further behind other Weather Service procurements. How will delays in implementing AWIPS affect the ability of the Weather Service to make full use of other observational capabilities such as NEXRAD? GOES-NEXT?

Answer:

A replacement for the existing National Weather Service information processing, display, and communications system (AFOS) is required to realize the full potential of the new data and to make it possible for forecasters to analyze, interpret, and disseminate key information under the urgent time constraints posed by fast-breaking, severe weather and flooding events. Delay in the introduction of AWIPS would also prolong the use of the obsolete AFOS system, thereby increasing the risk of degradation of services due to equipment malfunction.

The Weather Service is now in the final stages of preparing the solicitation for the Development, Deployment, and Operation of AWIPS. While a delay in deploying AWIPS may create the problems mentioned above, the President's FY 1991 budget requests an increase of $21 million for the development and deployment of AWIPS on a schedule that is consistent with the overall modernizatioin effort.

Question 5:

The NWS modernization will increase the amount and complexity of weather information received by individual forecasters. It will also require those forecasters to use new and technically complex types of equipment. What steps are being taken by the Weather Service to train employees to make effective use of the new systems which will be available to them? What role will the Modernization and Restructuring Demonstration (MARD) play in that training?

Answer:

During the next few years, the Weather Service training program will seek to ensure that all operational personnel have (1) a clear understanding of the latest theories and techniques in mesoscale meteorology and (2) adequately understand the new systems so that they can effectively use them to obtain significantly more information about the atmosphere at the level of the mesoscale.

Training for the Next Generation Weather Radar (NEXRAD) promises to be the largest training program ever undertaken by the Weather Service; the NEXRAD contractor (Unisys) is currently assisting the government to prepare for this training effort. All Weather Service operational meteorologists and hydrologists will attend a

4-week Operations Course in Norman, Oklahoma. The training class for each person will be closely linked to the equipment delivery date, so that the personnel are fully trained before the NEXRAD equipment is operational at a particular office. The training will cover NEXRAD product interpretation, operational applications, system description and system capabilities, as well as Doppler radar theory. Meteorologists from the National Severe Storms Laboratory and the NWS NEXRAD Instructor Team are currently developing a series of videotapes and workbooks on convection and storm structure and Doppler radar theory and interpretation; these will be distributed for prerequisite study by Weather Service personnel before their attendance at the 4-week Operations Courses.

Although final training implementation plans are not complete, the general strategy for the systems other than NEXRAD do not include centralized courses for all personnel. In the case of the Advanced Weather Interactive Processing System (AWIPS), we anticipate that a small number of key personnel from each office will attend a short centralized course. Training teams provided by the contractor will then provide systems training on-station to the remainder of the personnel.

The long-term NWS training strategy also calls for the development of an extensive "continuing education program" which will focus on operational meteorology at the level of the mesoscale. In September, 1989, the National Oceanic and Atmospheric Administration (NOAA) and the University Corporation for Atmospheric Research (UCAR) signed a Memorandum of Understanding to create a Cooperative Program for Operational Meteorology, Education and Training (COMET). This cooperative venture links the research and academic community to the operational community in a common effort to improve our understanding of mesoscale atmospheric processes, and to disseminate that knowledge to operational personnel.

A COMET Center located in Boulder, Colorado, will focus on two main activities: (1) development and distribution of computer-based training materials for an on-station study by operational personnel, and (2) development of short courses for selected operational personnel. The on-station training program will also include workshops conducted by subject matter experts from NWS National Centers, NOAA research laboratories, National Environmental Satellite, Data and Information Service, and elsewhere.

During the MARD, the NWS will implement its overall training strategy. The NEXRAD, AWIPS, COMET, and on-station training activities outlined above will also be conducted. However, because COMET will only have developed a small amount of computer-based materials by the time of the MARD, the COMET Center will also organize a special short course in operational meteorology for all the operational meteorologists and hydrologists assigned to MARD sites.

Answers to Questions from Senator James Exon for the Record of the October 26, 1989 Hearing Before the Senate Committee on Commerce, Science, and Transportation on the National Weather Service

Question 1:

In implementing the long-term program, there have been assurances from the Secretary of Commerce that there will be no closings prior to the implementation of the long term plan and that the long term plan will not result in a degradation in service. Does the Weather Service accept the Secretary's position and how will the Service assure no loss in service or safety?

Answer:

Yes. The National Weather Service policy for the transition is to comply with the certification requirements of Public Law 100-685, i.e., offices will only be closed as part of the modernization effort after the Secretary has certified that doing so will not degrade services. The transition approach that will be used to ensure this is an integrated, incremental step-by-step, office-by-office approach. The changes in operations and service related to modernization and associated restructuring are the ultimate guiding force for the transition. Future services will define the system outputs, the staffing type and mix of an office, and the field structure needed to efficiently provide these services. These, in turn, set requirements for training and education, facility preparation, and guide a myriad of other dimensions of the modernization and associated restructuring. The scope and pace with which implementation proceeds and service changes are effected will be guided by a realistic view of technology capabilities, and schedules to ensure continuity and quality of service.

Question 2:

One concern about the long term program is expressed in the old adage, "if it ain't broke, don't fix it." In essence, the new program trades a proven system for a new unfamiliar system. Has the proposed system been tested through pilot programs and what type of data can you produce to prove that the new technology is at least as good as the current system?

Answer:

New technological systems are essential in providing the opportunity to improve warning and forecast services and for replacing obsolete and increasingly unreliable existing systems. As today's weather service operational equipment complement has aged, it has become costly to maintain and more unreliable. Moreover, the existing national observing networks are sparse and limited in their coverage of the Nation's atmosphere.

Extensive testing, development, and operational demonstration activities have been pursued on the new systems for a number of years and will continue to be. For example, NOAA's Denver AWIPS Risk Reduction and Requirements Evaluation (DARE) project in Colorado; the development of a prototype Weather Forecast Office (WFO) at Norman, OK; and the Prototype River Forecast Center Operational Test, Evaluation and User Simulation (PROTEUS) project. Valuable experience has been gained with the demonstration of the new Automated Surface Observing System (ASOS) technology in the State of Kansas. Results from these activities and from other pilot programs have shown that the new technological systems are substantially better than the existing systems.

The Modernization and Associated Restructuring Demonstration (MARD) will be the centerpiece for demonstrating the fully modernized and restructured NWS of the 1990's. The primary objectives of MARD are to demonstrate that the planned WFO of the future can provide more accurate and timely warning and forecast services. MARD will take place in a multi-State area in the central United States which is extremely prone to severe weather. Once the proper number and mix of staff is in place along with the new technology, and training has been completed, the WFO's in that area, supported by RFC's and National Centers, will operate in the modernized and restructured mode as the first step towards national conversion to the new structure. Based upon the MARD experience, full implementation of modernized and restructured operations will proceed on a national basis in compliance with the provisions of Public Law 100-685.

Question 3:

In looking into weather issues, I was somewhat surprised at the apparent wall between the major Federal agencies with weather responsibilities. How much communication is there between the Department of Defense, NASA, the FAA and the National Weather Service? Is there a comprehensive Federal weather strategy? Was the long term plan developed with their input? Are there duplications of activities or checks and balances on the work of the agencies?

Answer:

The National Weather Service is part of a multi-agency group that has a comprehensive weather strategy plan as well as a system of checks and balances that prevent duplication of services by federal agencies. The Office of the Federal Coordinator for Meteorological Services and Supporting Research (OFCM) was established to promote coordination between the agencies involved in meteorological activities. Attached are further explanations of the policies and procedures for the coordination of Federal meteorological services and an explanation of the OFCM activities supporting those agencies.

Question 4:

The Weather Service utilizes impressive corps of professional and volunteer talent. The human factor in forecasting and observation is crucial. Machinery can break down, malfunction and now even be infected by computer viruses. Could you compare the role of human observation in the proposed system with the current system?

Answer:

The Nation does indeed rely on an impressive corps of professional and volunteer talent to provide observations that are critical to the weather mission. Driven by the opportunity to improve services and reduce costs, the National Weather Service (NWS), the Federal Aviation Administration (FAA), and the Department of Defense have entered into a joint program to field the Automated Surface Observing System (ASOS). The ASOS is intended to free up much of the routine effort of the government weather observer. It will also allow expansion of the observational network and provide observations from locations where none currently exist. This expansion is sponsored by the FAA's program to provide ASOS at smaller airports that are presently without weather observations. The ASOS will not remove the continuing need for the volunteer talent that supplements the Government's operations, and the NWS will continue to rely on this important source of weather information. Volunteer and cooperative observers will remain an essential component in future weather service operations.

With the existing observing system, NWS staff manually observe the weather while performing a myriad of other important assigned duties, e.g. conducting upper air and radar observations, recording NOAA weather radio broadcasts, and providing essential public services such as issuance of warnings and forecasts. The ASOS will provide more frequent station observations than the current system. It will operate continuously to provide 24-hour coverage of the weather, while freeing NWS staff to devote needed time to the other important assigned duties. The system will routinely provide weather information from many stations that are now operating on a part-time basis, and from many new locations that are currently without observations.

While modern technology brings with it the demand for sound systems management, it is recognized that equipment can and does break down. To minimize equipment disruptions, ASOS incorporates the latest in modern system design features, including continuously running, built-in system checks, remote maintenance monitoring capabilities, as well as some redundancy in critical system components. During the incorporation of state-of-the-art technology features, operational back-up procedures will be established for utilizing human observations at staffed locations in order to ensure continuous essential weather services.

Answers to Questions from Senator Slade Gorton for the Record of the October 26, 1989 Hearing Before the Senate Committee on Commerce, Science, and Transportation on the National Weather Service

For Dr. Knauss

Question 1:

Last year NOAA announced that a contract weather service station at Stampede Pass, Washington would close. This station was manned by a human observer who provided visual observations which were widely used by pilots. Despite an outcry from private pilots, the Congressional delegation, and the Governor, the station was closed. Shortly thereafter a private plane was lost in the Cascades. Many people feel this was due to inadequate weather reporting. In fact, in the past one of the most helpful tools in locating the site of a plane crash was the use of this type of data as it would tell us where weather front lines were. The Appropriations Committee has included $200,000 to reopen this station, and two others closed in Oregon. Do you intend to implement this Congressional directive?

Answer:

Yes. We already have a temporary employee at Stampede Pass taking observations 40 hours per week and plan to award an observation contract on or about March 1. Sexton Summit is back to prior observation; observer training is underway at Blue Canyon.

Question 2:

Earlier this year I remember hearing that we lost the capability of a GOES satellite. What type of data have we lost because of the loss of this satellite? What is the schedule for the launch of the next GOES?

Answer:

Standard GOES operations call for a two-satellite configuration. The GOES data include imagery and derived products used to support NWS warning and forecast programs. With the loss of GOES-6 in January 1989, the area of east-west coverage provided by GOES over the eastern Atlantic and central Pacific Oceans shrank approximately 1550 miles. However, the impact from the loss in coverage is minimized by periodically moving the remaining GOES-7 according to NWS requirements. For the winter storm and severe storm seasons (November to June), GOES-7 is positioned at 108°W to provide a better view of the storms moving in from the eastern Pacific. For the hurricane season (July to October), GOES-7 is moved to 98°W to provide a better view of the developing tropical storms over the Caribbean and Atlantic. The current projected launch date for GOES-I is scheduled for June 1, 1991.

Question 3:

Do the automated stations have the capability of giving a full sky forecast? By that I mean, I understand the system looks up and reports what is overhead, but could it fail to report a cloud bank beginning to move in from one direction?

Answer:

Automated stations have fully demonstrated the capability of providing sky condition observations. Extensive testing of automated methods have been conducted by the National Weather Service, the Federal Aviation Administration, and the Defense Department over the last decade, and the method has been approved to support aviation and other operations.

It is unlikely that an automated station would fail to report a cloud bank moving in from one direction. This issue was a prominent concern in development efforts in the 1970's. Initially, early testing relied on a network of three Cloud Height Indicators (CHI's) arranged in a seven-mile triangular configuration about an airport. The data from the CHI's were then processed by a 30-minute statistical averaging technique to determine sky condition. The results of this testing determined that in the vast majority of cases, a single CHI was sufficient to consistently determine cloud height and sky coverage as well as human weather observers.

To better understand the detection methodology, it is necessary to understand how clouds actually move or form. Early work was based on the premise that as a front approached an airport there would be a gradual increase of clouds and lowering of cloud heights. What actually occurs, however, is similar to the development of fair weather cumulus clouds, i.e., clouds develop rather suddenly and randomly throughout the sky. When a weather front approaches, a cloud deck would not approach uniformly but rather patches of clouds would appear randomly over the sky at approximately the same height. This phenomena comes from large scale uplifting within the frontal zone. Consequently, instead of clouds moving in, a moisture layer advects over the airport, large scale lifting occurs and randomly spaced clouds appear at the height of the moisture layer. As a result, only a single CHI is generally needed to detect and determine cloud height and amount.

There are some special cases, however, in mountainous terrain or near large bodies of water which may have non-uniform sky formations. In these locations, an additional CHI may be needed to adequately sample and determine sky coverage. To accommodate these special cases, individual site surveys will be conducted to determine this requirement prior to the automated system installation.

For Dr. Sheets

Question 1:

You said you have two planes to fly through hurricanes, and the Air Force has ten. The Air Force tried to terminate this program earlier this year. What would have been the effect of losing Air Force capability on your ability to forecast hurricanes?

Answer:

On April 7, 1989, I testified before the Subcommittee on Natural Resources, Agriculture Research and Environment of the Committee on Science, Space and Technology of the U.S. House of Representatives on the above subject. That testimony provides background and overall impacts of aircraft on the forecast and warning process. Following is a summary of that testimony.

On average, the difference between having reconnaissance aircraft information and not having it available means not knowing the strength of the storm within one category on the Saffir/Simpson scale and occasionally mislocating weaker storms and hurricanes by more than 100 miles. Also, there are no other means available today to determine the strength and distribution of the winds within the core of the storm and regions of heavy rains. Knowing these factors is critical to the forecast and warning process. A survey of strong hurricanes from 1979 through 1989 found that for every strong hurricane during that period, the satellite-based estimate was in error by at least one category and at times two categories at least once during the life of each of these storms. For instance, satellite based estimates of the strength of hurricane Hugo on September 15, 1989 were found to have underestimated the strength by two categories when the first reconnaissance aircraft arrived on the scene. The maximum sustained winds were 160 mph as compared to an inferred 130 mph from the satellite based estimates. The impact of differences of response is considerable for even one category change in strength. For instance, if a category 2 hurricane moves inland over the Galveston/Houston, Texas area, tens of thousands of people must be evacuated to escape the rising waters which inundate barrier islands and low lying coastal regions. If the wind speed is only 20 mph stronger (category 3) the number of people who need to be evacuated **increases** by more than 200,000! Similar situations are shown in the attached document from testimony before a House committee for locations such as the New

Orleans, Louisiana, Atlantic City, New Jersey and southwest Florida areas. Position errors also create major problems. Last November, Tropical Storm Jerry was located in the middle of the Gulf of Mexico and moving northward. All was going well during the day of November 13 with combinations of satellite and reconnaissance aircraft data. However, during the night of the 13th and early morning hours of the 14th, two Air Force planes had mechanical problems resulting in no aircraft observations during a critical 13-hour period. Satellite estimates from two different operational units which had been in good agreement with previous aircraft information indicated the storm was starting to move faster toward the Louisiana coast. This apparent increase in forward speed of only two to three knots meant that a Hurricane "Watch" had to be issued for the coast of Louisiana during the late evening of November 13. Previous assessments indicated that we could wait until the next day to issue the "Watch," and since there was considerable uncertainty in the forecast strength and track, a delay would result in a much more accurate forecast and reduced overwarnings. When the aircraft arrived on the scene the next morning, it was discovered that the satellite estimates had mislocated the storm by more than 60 miles! Furthermore, satellite estimates from two different units differed by more than 60 miles. The result was an unnecessary "false alarm" for the southeastern Louisiana coast.

NOAA has two research aircraft capable of flying into hurricanes. These aircraft supplement Air Force aircraft for operational forecasting purposes in critical situations such as 24 hours before landfall and when a hurricane is in restricted air space such as around Cuba (NOAA aircraft can over-fly Cuba). If these aircraft were diverted to full-time operational duties, there would be a major loss to the research community. In addition, the two aircraft would not be sufficient for following a single hurricane such as Hugo, let alone a combination of storms such as Hugo and Iris which were occurring at the same time, or as has happened in the past, a storm threatening Hawaii, one in the Gulf of Mexico, and one in the Atlantic and/or in the Caribbean.

In summary, in my opinion, the loss of the reconnaissance aircraft capability would result in greater and more expensive overwarnings, and ultimately, more lives would be lost because of the complacency generated by the perceived "cry wolf" syndrome.

Senator **Gore**. I want to thank you on behalf of the subcommittee for being here today.

Dr. Knauss, just a final word. I hope that you will reconsider during that Monday meeting. With that, we will go to our next witness. Thank you very much.

Senator **Stevens**. Mr. Chairman, as he leaves, Dr. Sheets, my oceanographers tell me that the Arctic Oceans are actually getting colder. Do you have that same information?

Dr. **Sheets**. I do not monitor the Arctic very well from the tropics, but, indeed, we have not seen much of a change there, and there are a lot of uncertainties in that, as you have indicated.

Dr. **Knauss**. One thing we are learning, sir, is the ocean has its own climate. It goes up and down just as you can have hotter summers in the New England area in some years than others. We used to think that the ocean temperature is always the same. It is not always the same. There are fluctuations.

Senator **Gore**. The ocean contains 50 times more carbon dioxide than the atmosphere.

Dr. **Knauss**. Thank goodness.

Senator **Gore**. Thank you three very much.

Our next witness is Mr. David Powell, President of the National Weather Service Employees Organization from Soddy-Daisy, Tennessee. We are delighted to have you here.

Let me apologize to you and to the witnesses on our third panel for the fact that we have gone longer than anticipated. Please summarize your statement. It will be included in the record in full.

We are delighted you are here, and we look forward to hearing from you.

Senator **Stevens**. My apologies to you and the rest of the witnesses here. I have an appointment downtown, so I have to leave. Thank you.

Senator **Gore**. If this witness was from Alaska instead of Tennessee, you would stay here.

STATEMENT OF DAVID T. POWELL, PRESIDENT, NATIONAL WEATHER SERVICE EMPLOYEES ORGANIZATION, SODDY, DAISY, TN, ACCOMPANIED BY JOHN CHWAT

Mr. **Powell**. I spent three years in Alaska.

Senator **Stevens**. As a practical matter, if he was going where I was going, he would go, too.

Senator **Gore**. I know that is true. Thank you, Senator Stevens.

Mr. Powell, please proceed.

Mr. **Powell**. Thank you for allowing us to come here today to voice our concerns on the modernization of the National Weather Service. I am the President of the National Weather Service. Of course, I am stationed at Chattanooga, Tennessee. I represent a union of employees in the National Weather Service as well as NESDIS. NESDIS are the people who take care of the satellite reception.

Now our organization in its testimony before Congress has always tried to focus on two primary themes: protecting both public safety and the long run cost effectiveness for the American taxpayer. We are excited about a new and revitalized Weather

Service, but we do have serious concerns. I would like to share those concerns with you here today.

Mr. Chairman, at this time we would like your permission to insert into the permanent record of this hearing a three-page document dated August 23, 1989 entitled, "NWSEO Comments on National Weather Service National Implementation Plan," and the May 1989 22-page document by our organization that is entitled, "Response to the Strategic Plan for Modernization and Associated Restructuring of the National Weather Service and Recommendations."

Senator Gore. We will be glad to get that and it will be incorporated by reference. Thank you.

Mr. Powell. The National Weather Service implementation plan continues to include about 115 forecast offices, and that is about 135 less offices than we have today. We believe that this number will prove inadequate to properly serve and protect the citizens of the United States. We believe that coverage must be driven by the capability of the technology and not funding.

Staffing of weather forecast offices of the future is really inadequate. Their plans call for fair weather staffing. Now this means single coverage on midnight shifts. As you know, weather does occur around the clock. It has no time limits. Single coverage staffing is really inviting a disaster to happen.

The government reduced the number of FAA aircraft inspectors, and this led to an increased incidence of accidents caused by deficient aircraft.

It also reduced the number of meat inspectors in the Department of Agriculture, and this led to an increase in food poisoning.

The government reduced the number of air traffic controllers, and this has led to an increased number of near collisions. The same with OSHA inspectors, and this has led to an increased number of on-the-job accidents.

The government reduced the number of weather employees, and this has led to the deterioration of the nation's forecast and warning services. Instead of reducing weather service staff and offices, we believe that Congress and the American people should demand a strengthened National Weather Service.

The National Weather Service modernization plan is not driven by adequate meteorological coverage that is going to be provided by the new technology, but rather it is being driven by further reductions in staff. NEXRAD and ASOS really are still unproven technologies.

We believe that NEXRAD is a step in the right direction, but the new technology is not proven and it is wrong for NOAA to tell the Congress, this subcommittee and the American people that these expensive new technologies will be the sole savior of the National Weather Service's mission and an adequate replacement for the National Weather Service work force.

Until NEXRAD and ASOS have been tested successfully, we do not believe that Congress should commit itself to full scale procurement of these new technologies at the expense of current staff and services.

We do agree that there is an impetus for major change in the weather service provided by new technology and advanced science, but we must not allow this new technology to be oversold or to allow budget considerations to control the extent of the application of modernization.

We also note with concern that scarce resources, especially in the area of staffing levels, can be expected during this transition period. It is our fear that the lowered staffing levels will be carried into the new weather service, and it really appears that the concept of fair weather staffing is planned and will be carried into the new weather service. I have stated that a little earlier in this testimony.

The National Weather Service has always been a very highly visible government service and at a cost of, oh, roughly $1.25 per person per year, we think it is a pretty good deal. We hope to see a modernized weather service, one that will provide services as good if not better than what the current structure does. I believe that if management and the union work together, probably that will happen, and I hope that the members of your subcommittee agree.

I would like to thank you, Senator, for the opportunity to appear before your subcommittee and to voice our concerns.

[The statement follows:]

STATEMENT OF
DAVID POWELL, JR., PRESIDENT
NATIONAL WEATHER SERVICE EMPLOYEES ORGANIZATION

Mr. Chairman and Members of the Subcommittee, my name is David Powell and I am President of the National Weather Service Employees Organization (NWSEO). I am stationed at the Weather Service Office at Chattanooga, TN. and represent a union of employees in the National Weather Service (NWS) and the National Environmental Satellite Data and Information Service (NESDIS) both within the National Oceanic and Atmospheric Administration (NOAA). All of our members are engaged in observing, forecasting and disseminating weather information. Accompanying me is John Chwat of Chwat/Weigend Associates, our lobbying firm.

Our organization in its testimony before Congress has always tried to focus on two themes; protecting both public safety and the long run cost-effectiveness for the American taxpayer. While NWSEO is excited about a new and revitilized weather service, we do have serious concerns, concerns that I would like to share with you today.

Mr. Chairman, at this time we would like to request your permission to insert into the permanent record of this hearing an August 23, 1989, three page document, entitled "NWSEO Comments on NWS National Implementation Plan" and a May, 1989, twenty-two page document by the NWSEO entitled, "Response to the Strategic Plan for the Modernization and Associated Restucturing of the NWS and Recommendations."

I. REDUCTIONS IN NWS FORECAST OFFICES

The NWS Implementation Plan continues to include 115 Weather forecast office may be a hundred miles or more away and will not be able to serve the communities as well as they do now. Contact with local spotter and civil defense groups will be lost and, as a result, service will be degraded and public support will be eliminated. As taxpayers, the public is paying for a form of insurance and they deserve the best coverage available. Coverage must be driven by the capabilities of the technology, not funding.

II. REDUCTIONS IN NWS STAFFING

Staffing at Weather Forecast Offices of the future are inadequate. Plans for staffing call for "fair weather staffing", with single coverage on midnight shifts. Weather occurs around the clock, it has no time limits and single coverage staffing is inviting a disaster to happen. It is not a question of affording two additional meteorologists, but, rather, can we afford not to protect the public.

The government reduced the number of FAA aircraft inspectors and this led to an increased incidence of accidents caused by deficient aircraft. The government reduced the number of meat inspectors in the Department of Agriculture, and this has led to a steadily increasing rate of food poisoning. The government reduced the number of air traffic controllers, and this has led to an increased number of near-collisions. The government reduced the number of OSHA inspectors, and this has led to an increased number of on-the-job accidents. The government reduced the number of weather employees, and this has led to a deterioration in the nation's forecast and warning services. Instead of reducing the weather service staff and offices, the Congress and the American people should demand a strengthened National Weather Service.

Our main point is: "enough reductions!" NOAA management has gutted the National Weather Service without any new technology in place. The National Weather Service modernization plan is not driven by adequate meteorological coverage to be provided by the new technology, but rather by further reductions in staff. The American public deserves adequate coverage with proven technology, and this can only occur without further reductions, but also an increase in the level of staff up to the number of positions already authorized.

III. NEXRAD AND ASOS ARE UNPROVEN TECHNOLOGIES

While the NWSEO believes that NEXRAD is a step in the right direction, these new technologies are not proven and it is wrong for NOAA to tell the Congress, this Subcommittee, and the American people, that these expensive new technologies will be the sole saviour of the National Weather Service's mission and an adequate replacement for the National Weather Service work force.

In addition, the doppler feature range limitations within the NEXRAD system are inadequate for the job. Planned sites with only a 40 to 50 mile doppler range would not have detected the North Carolina or South Carolina tornadoes, and would have missed other severe weather occurances.

In order to better serve the taxpayer, more NEXRADs and WFOs are needed. Otherwise, a tragedy of great proportions may occur, without the possibility of warning. NWS Implementation Plans are not quite spelled out, but it appears that future offices are to be moved away from airport locations. In order that there is no loss of surface weather observations, the Automated Surface Observation System (ASOS) was developed. ASOS is a machine, and machines have limitations. For instance, ASOS, at this time, cannot detect thunder or snow or freezing drizzle and rain. Smaller airports will have only one set of ceiling and visibility measuring sensors while larger airports will have two. Observations, vital to aircraft operations will be degraded, unless augmented by a human observer. Equipment malfunctions will be monitored by a central location, and when a malfunction occurs, backup systems will be activated by maintenance at a remote location. If backup systems cannot be activated, a technician will be dispatched to correct the problem. This means that ASOS may be out of service for several hours and a human observer will have to take over, NWSEO believes that this will seriously degrade aircraft safety and that weather offices should remain at airports.

We agree, Mr. Chairman, that ASOS has been tested more thoroughly than NEXRAD, but the results of these tests demonstrate that fully automated weather observations are not now technologically feasible.

A National Weather Service internal report, which our organization obtained through the Freedom of Information Act (FOIA), revealed that nearly every ASOS sensor failed in some way during a pilot project in Kansas. ASOS was incapable of detecting cloud height cover above 10,000 feet, and the cloud height indicator occasionally failed to detect stationary or widely scattered cumulus clouds. The cloud height indicator reported false readings during mild precipitation and failed completely during heavy precipitation. The ASOS laser weather indicator failed to adequately discriminate among rain, snow, drizzle, hail, sleet, and mixed precipitation. Lightning and freezing rain were detected with only partial success. The internal report concluded that ASOS "did not demonstrate adequate present weather detection capability."

Until NEXRAD and ASOS have been tested successfully, the Congress should not commit itself to full-scale procurement of this new technology at the expense of current staff and services.

NWSEO agrees that there is an impetus for major change in the NWS provided by new technology and advanced science. We must not allow the new technology to be oversold, nor to allow budget considerations to control the extent of the appliction of modernization. We also note with concern that scarce resources, especially in the area of staffing levels, can be expected during the transition period. It is our fear that the lowered staffing levels will be carried into the new weather service, and it appears the concept of "fair weather staffing" is planned and will be carried into the new weather service as I've stated in eariler in this testimony.

The National Weather Service has always been a highly visible government service, and at a cost of about $1.25 per person a year, it is a very good deal. We hope to see the modernized weather service one that will provide as good if not better service to the public than the current structure. If NWS management and NWSEO work together I believe that it will be. I hope that members of the Subcommittee agree.

Thank you for the opportunity to appear before your Subcommittee and to voice our concerns.

Senator GORE. Thank you very much, and you are accompanied by John Chwat.

Let me congratulate you on your statement, Mr. Powell, and your written statement, as I said, will be included in the record.

Now, only three weather forecast offices are included in the strategic plan for Tennessee; Knoxville, Nashville, and Memphis. For that reason, is one to presume that, under that plan, the office in Chattanooga is slated for closure?

Mr. POWELL. The office in Chattanooga as well as the Tri-cities will be slated for closure under the modernization plan which essentially means these two communities or cities would lose their local weather offices, and there is even a bigger impact.

The weather service also depends very heavily on civil defense people, law enforcement agencies and ham operators to help us out when we have what appears to be severe weather, places where we have flash flooding or tornado activity. These people really become one of our first lines of information.

Senator GORE. What services currently provided by the Chattanooga office and the Tri-cities office will not be provided if the station is closed? Some of them will be replaced by the automated system, but which will not be provided after the station is closed, if it is closed?

Mr. POWELL. If the station is closed, they will still have the NOAA weather radio. However, it will be remoted out from Morristown, I think, or Nashville. So, you will lose your local coverage there. The forecast will be issued either out of Morristown or Nashville. You would lose public contact primarily.

I have not really seen anything in the plan. I would assume that they would allow an 800 number, one 800 number to contact one of those weather offices, but if that is the case, I would hate to be working at one of those offices.

Senator GORE. What has been the reaction in the community to the proposed automation of the ground observation system? I can claim a little expertise on this question, but I want to hear it from you.

Mr. POWELL. Well, the observation system—I do not really think a lot of people understand what it entails. For smaller airports they will have approximately one set of sensors for ceiling and visibility and such as that.

The larger airports, will have multiple sets of sensors. However, these sensors are not going to pick up clouds, say, above 10,000 feet, and in many cases if you have a fog bank occur and start to weave across the field, it will not really show a good prevailing visibility or, for that matter, runway visibility, and I am afraid the system will have to be augmented by a human being.

And who is going to do the augmentation? The trend right now is to move away from airports with weather services offices and that means they will either have to cut somebody loose from the weather service office to physically go to the airport or have the FAA controller people do it, or have a contract observer on standby.

Senator GORE. Well, I can add to the record here by saying that in both communities there has been extreme concern accompanying the announcement of these plans, and I assume that employee morale has been affected by the proposed decrease of 585 positions in the NOAA budget for fiscal year 1990.

Mr. POWELL. Well, definitely across the entire nation employee morale has decreased, and I think one reason for this is nobody really knows what the plans are.

Senator GORE. Now, the strategic plan also includes four principles essential to meet the operational mission of the weather service. The second principle states that employees will be involved in the modernization and associated restructuring process, and I quote, "because their participation is crucial to a successful transition and improved operations."

It goes on to state that "Significant levels of training and education will be provided so that employees will gain the necessary expertise to utilize the new technologies."

Have members of your organization been consulted in developing the strategic plan or the national implementation plan?

Mr. POWELL. We have been given two modernization briefings. We were given a draft plan of the August—the latest one—on which we made some comments. Of course, we made comments on the original plan that came out in April. Other than that, no.

Senator GORE. What steps are being taken by the weather service to train employees in making effective use of the new systems?

Mr. POWELL. As far as we know, right now they have been training some people at Norman in the use of NEXRAD facilities. I cannot speak of the training, I cannot speak of what they have actually done because these people were required to sign a nondisclosure statement, and so they could not discuss it with us.

Senator GORE. I have some other questions for the record, Mr. Powell, and the other members of the committee may also. I want to congratulate you again on your statement. You do an outstanding job advocating the interests of the National Weather Service employees, and I look forward to working with you closely as we continue to deal with these issues.

Mr. POWELL. Thank you very much.

Senator GORE. Thank you very much, Mr. Powell.

Our final panel is made up of Dr. Richard Hallgren, Executive Director of the American Meteorological Society based in Boston, Mr. Bob Ryan, Chief Meteorologist of WRC-TV here in Washington, Dr. Kerry Emanuel, Center for Meteorology and Physical Oceanography at MIT in Cambridge.

Gentlemen, let me apologize again for the length of time it has taken us to get to this panel. The vote intervened and the discussion with the first panel intervened, but we certainly appreciate your patience and look forward to your statements. The prepared statements, as I have said with other panels, will, of course, be included in full in the record, and we will begin with your oral presentation, Dr. Hallgren. Thank you very much for being here. We look forward to hearing from you.

STATEMENT OF DR. RICHARD HALLGREN, EXECUTIVE DIRECTOR, AMERICAN METEOROLOGICAL SOCIETY, BOSTON, MA

Dr. HALLGREN. I appreciate the opportunity to be here before your committee.

Some of my thoughts will obviously be based on my past personal experience, but I would like to start with the broad directions for the atmospheric sciences.

One year ago the American Meteorological Society and the University Corporation for Atmospheric Research prepared a report recommending two top priority actions for the decade of the nineties in atmospheric sciences. One was, of course, the topic of today's conversations, to improve the severe weather and flood warnings and weather predictions. The second one was for the United States to combine with other nations to develop the understanding needed to anticipate the course of climate-related events, to estimate their impacts, and to prepare for future change.

These two recommendations, as you well know, have to do with important issues that are of major policy concern to this country and the world. They address very different needs in two separate areas. However, some of the research activities for these two programs are interconnected.

Today we are focusing on the protection of life and property of the people of the United States. The importance of this activity was made very clear by Hurricane Hugo, by Hurricane Jerry, and the north California earthquake. These three events are fresh in our minds, but we must not forget in the course of the year tornados, flash floods, winter storms and forest fires all took their toll in various parts of the country.

We have major opportunities, both scientifically and technologically to make great advances in these areas. We must put this knowledge to work.

In my opinion, three parallel streams of action are required. One is to get on with the modernization of the weather service. That is not only the technology, but also it has been brought out a number of times this morning, by arranging for the wise use of personnel to ensure the effective application of the science and technology.

The second one is to undertake the national research effort to increase our scientific understanding of severe storms and their prediction through the joint efforts of research laboratories and the university community and to translate these results into improved operations.

And third is to develop improved preparedness plans. Preparedness planning is an extremely important part of the process of protecting life and property. Time after time during the period I was director of the U.S. Weather Service disaster survey reports showed that if a city or county had given serious attention to their preparedness efforts, the warnings of the weather service were much more effective in savings lives and reducing property. And I think Hugo with the evacuation that took place shows that. But it is not clear to me the evacuation plans for recovery were in place.

Only one of these three streams of action is underway at this time and that is the modernization of the weather service. It is time for this nation to address the other two streams with equal vigor.

With regard to the modernization of the weather service, we have talked about the technology here this morning. What is now required is the determination to continue the funding with these systems, the satellites, the radars, the AWIPS, and computers to ensure their deployment at the earliest possible time.

But equally important is the way we utilize the forecasters in the offices of the weather service across the country and the way in which we prepare them to make full use of this new technology.

We must ensure that the weather service offices are adequately staffed both in number of personnel and professional capability and that a continuing education program is undertaken in collaboration with the university community to ensure that forecasters are kept up to date of the scientific advances, especially in mesoscale meteorology.

I have a deep concern that the pressure to reduce—and I felt it when I was director of the weather service—the number of personnel and limit the investment in a sound and comprehensive continuing education program will be so great that the nation will not derive the full benefits from a modernized weather service.

It would be penny wise and pound foolish to reduce personnel too far and not to provide for adequate continuing education. The type of technology that is being deployed will increase productivity, but will lead only to a modest reduction in the number of personnel. What it can do is tremendously increase the quality of severe weather and flood warnings and weather predictions.

The number of offices that issue severe weather and flood warnings can be reduced with the new technology being deployed, but not before the technology and other arrangements are in place and fully operational.

The staffing of some offices must be increased and other decreased. However, we must not lose sight of the need for contact with the media, emergency management group, and more generally the people in local areas. They must know how to obtain warnings, understand them, and take appropriate action related to their safety.

In addition, we must ensure that the volunteer severe storm and flash flood spotter networks and the volunteer climatological observer network are kept intact. The modernized weather service must be staffed to accomplish these functions. In order to carry out these functions, in my opinion, we should consider maintaining a staff of one or two persons at all existing stations, even if they will not issue warnings.

Severe storm research program is another major effort that must be undertaken if we are going to get the full benefit from the modernized weather service. What is required is a national research effort involving research laboratories in the university community again. This community has already developed a good program plan. It is called STORM. This program will increase understanding of the physical processes of small scale motions of the atmosphere, and it is time that we move on with that.

I cannot believe that we should not make that additional investment in carrying out this national research program to get the full benefit from the modernized weather service and all the technology that is being put in place.

Preparedness planning is the third topic that I said I wanted to say a few words on. Two decades ago, Mr. Chairman, there was very little preparedness planning done across this country. Since then we have made substantial progress. Most cities and counties have formulated preparedness plans, but they vary in quality over a very wide range.

And while we can sit and say that it is the responsibility of the local communities, I think we should face that what is really required is a sound, coordinated local, state and federal plans that are exercised and tested prior to disasters. Such plans would go a long ways toward alleviating the suffering that is inflicted by the various disasters.

It is time, I think, the federal government recognizes its responsibility to assist fully in the development of these plans. A national focus on preparedness planning is essential. It would not require a large increase in funding.

The weather service would be involved, but the leader must be the Federal Emergency Management Agency. In the last few weeks, although some of us have been talking about it much earlier, people have recognized that the agency has not had the leadership, has not had the funding.

It was created in the late seventies and just has not received the policy attention that it should have gotten over the years. And it is time we do it.

And also FEMA, in my opinion, ought to shift its priorities away from what man can do to man, namely nuclear disasters, to what the environment is doing to man, natural disasters. And with just that step we would go a long way in getting the effort going that is required while FEMA leads many agencies in carrying out proper preparedness planning.

In summary, I think we are on the right road, but we have made a commitment to the most costly element, the modernization of the weather service. We must see it through, but I firmly believe we must get on with a national program on severe storms research and a major national program to improved preparedness planning. Thank you, Mr. Chairman.

Senator GORE. Thank you very much. Mr. Ryan, I get a lot of my weather information from you, and I know I speak for a lot of people in expressing thanks for the great job that you do. We are delighted to have you here as a meteorologist on this panel. I have had an opportunity to hear you testify before, and I am glad to have this chance, so please proceed.

STATEMENT OF ROBERT T. RYAN, NBC METEOROLOGIST, WRC-TV

Mr. RYAN. Thank you very much, Mr. Chairman. It is a pleasure and an honor for me to talk about a science I love and actually get a little bit more than two and a half minutes to do it, too, so maybe even I will double that time.

Let me first talk about the role of the private sector, which I am pretty familiar with, in the meteorology of the United States. If we agree that one of the fundamental functions of government is the protection of the lives and property of its citizens, then few government organizations meet that function day in and day out like the National Weather Service, as I think Senator Stevens pointed out so well.

The mandate of the National Weather Service has been and should always be the dissemination of public forecasts and the issuance of watches and warnings required to safeguard the lives and property of its citizens. Sometimes, as we have just seen so graphically in the case of Hurricane Hugo, an excellent forecast can save lives but do little to allow for complete protection of property.

Complementing this broad mandate is the work of the private sector in meeting the needs of specialized groups, localities, industries, or other users of weather information or products. The special needs may range from a trial lawyer who wants to know if the ground was snow-covered on a certain date, to a power company that wants a display of cloud to ground lightning strokes in their coverage area.

Interestingly, as the science of meteorology has made significant advances and we have been able over the years to use the best of American science and technology to tackle the forecasting problem, these advances have opened new industries and created significant growth in the private sector.

As with so many areas of science, as we have learned more, we have found more uses for what we have learned. Good old American initiative is alive and flourishing in private meteorology.

The private sector's development has almost always been in areas which serve the needs of the users which would complement the fundamental role of the National Weather Service. The dissemination of more accurate weather data and weather forecasts to the public has gotten more extensive and more timely over the years, but it cannot be done without a strong working relationship between the public and private sector. The best forecast is worthless if no one hears it, and the most timely warning does no good if no one acts on it.

The role of the National Weather Service in being the critical, fundamental source of weather data and weather products—raw data, computer products, the radar and satellite data—made available to all users and being the source of public forecasts and weather warnings should not change, and if necessary should be reaffirmed as strongly as possible.

The private sector, which has grown so much and plays a vital role in the dissemination of weather information in specialized services, cannot meet its needs if the free flow of needed data and products is diminished in any way because of modernization.

Let me talk about the modernization and how it will affect the private sector. I think all meteorologists agree that the modernization efforts of the National Weather Service through the implementation of the NEXRAD network nationally, GOES-NEXT, automation of more surface observation sites, the ASOS program, more remote sensing such as Profiler, the ALERT system and the centralization and greater computer capacity will result in better forecasts, better forecast products, and faster dissemination of critical watches and warnings to the public and better weather data and weather products for all meteorologists.

I think critical attention, though, needs to be paid that these programs now underway are maintained at needed funding levels and put into operational service without budgetary or political delay. NEXRAD has been planning for many years and field installation is just beginning, but procedures and plans are only now beginning to be spelled out as to how NEXRAD products will be available to broadcast meteorologists and to other outside users.

NEXRAD is a powerful meteorological tool and will provide National Weather Service and private meteorologists with new information which will improve short-range forecasts and warning lead time during severe weather. Access to these critical products for private meteorologists and especially broadcast meteorologists will benefit many users and provide the public with additional information and confidence in necessary watches and warnings.

People who hear weather warnings without seeing what the danger is, or any understanding of the basis of the warning, may not feel the need to take action. All new products and data generated as a result of modernization should be as easily available to the private sector as National Weather Service data and products are now. This should be reaffirmed to the private sector.

No one, I do not think, would benefit by making access to new data difficult or restricted, and it also continues to be critical to maintain the excellent working relationship between the private sector that it enjoys now with the public sector.

I think one area that we have heard so much about, about the National Weather Service modernization which has received criticism, is the centralization efforts which will result in closing many smaller national weather service offices and part-time offices.

There is, I think, legitimate concern by people in the local National Weather Service areas of responsibility that they will not be as well-protected by a forecast office that may be hundreds of miles away, rather than the local National Weather Service forecast office which may have served the community for years.

I believe it is important, during the transition time, as modernization goes forward, there be a vigorous education effort to inform the public about the modernization and the centralization and what the advantages are: how the forecast products will be improved, how the public, even far removed from a central forecast office, will be given even better coverage and protection. Any education effort is another example of where there should be—and would be, I think—close cooperation between the public and private sector.

Let me talk about the public response to Hurricane Hugo. You asked me to talk about that. It will certainly go into the record books as the most costly hurricane ever to strike the United States.

I personally feel the National Weather Service, and in particular the National Hurricane Center, did an outstanding job of keeping the public informed about the course of the hurricane, issuing the watches and then warnings which allowed for an orderly evacuation and kept the loss of life to a remarkably low number, considering the damage caused by the storm.

Indeed, the relatively low loss of life from this tremendous hurricane is a credit to the advances in the science of meteorology and communication systems we now have. A similar hurricane 50 years ago almost certainly would have resulted in the loss of hundreds or thousands of lives.

Hugo also gave us another reason to see that funding for hurricane reconnaissance aircraft not be cut or reduced. During the critical night-time hours before landfall, aircraft were continually probing Hugo, and aircraft were able to measure some strengthening and acceleration in speed and give critical information to forecasters to better prepare the coastal location where landfall was made.

Any cutback or termination of hurricane reconnaissance aircraft would only, in my opinion, make the hurricane forecaster's job more difficult and could unnecessarily risk lives along the coast.

The media coverage of the progress, landfall and damage from Hurricane Hugo was intense, and the ratings for all network and local news programs during this time were among the highest of the year. People were concerned about Hugo and wanted as much news guidance and forecast information as possible.

One individual stood out during this time—and we met him today, Dr. Bob Sheets—director of the National Hurricane Center, who made himself available around the clock to all national and local news programs. His information and discussions were always geared to keeping everyone informed, raise concerns where necessary while avoiding unnecessary speculation, and all the time remaining calm and deliberate.

The cooperation of the public and private sector during Hurricane Hugo is another example of how the entire meteorological community works together to provide the best forecast information and weather data to the public. For both the public and private sector, the modernization plans and changes to come in the next few years of the National Weather Service are critical to keep on course with a minimum of delay.

Because of some delays in the past due to budgetary or political decisions, implementing the necessary changes and advancement in the three critical areas of satellite, radar and surface observations may not be going as smoothly as possible and may be a bit more difficult, but the Nation's weather services are on a path which will give the country even better, more accurate and more timely weather forecasts and warnings.

It is imperative that the plans developed and now underway be vigorously supported and funded. We have the best pool of scientific talent, computer know-how and space technology in the world. The one science which can benefit the most from these areas and be of greatest benefit to the general public is forecasting the weather and safeguarding our citizens from weather-related natural disasters.

The weather services of the future, with the continued cooperation of the public and private sectors, and continued access to all available weather data, will ensure that the public is better informed, understands what is likely to happen, will be given more accurate information with a longer lead-time during severe and life-threatening weather, and will continue to support and see the benefit of our Nation's weather services and the need for continued research on the many atmospheric problems.

Thank you very much for the opportunity to present this statement.

[The statement follows:]

Statement of Robert T. Ryan

Thank you Mr. Chairman, it is an honor and a pleasure for me to talk a bit about the science I love, a science which, as we have seen recently, can have a tremendous impact on peoples lives, and a science which just about everyone talks about each day. I should add that while I am a meteorologist for WRC-TV, the NBC station here in Washington, and serve as Commissioner of Professional Affairs with the American Meteorological Society, the views I am presenting are entirely my own.

HISTORY AND CHALLENGE OF FORECASTING

Meteorology is still a rather young science. An understanding of the physics and processes of our atmosphere really only took place beginning about sixty years ago. Picture the problem which faces the weather forecaster. You are given a complex atmosphere, a mixture of gases about 10 miles deep on an rotating spheroid 8000 miles in diameter nonuniformly heated by a nuclear reactor 90 million miles away. The atmosphere is a mixture of gases having different physical properties and then the heat from the nuclear reactor is absorbed differently by different materials on the spheroid at different times of the year. The meteorologist is then asked to predict the concentration and state (gas, liquid or solid) of one part of that mixture that makes up only a very small part of the atmosphere. That is, will the water above us (only 0.001% of the total water on earth) be in the form of clouds, rain or snow or will it be in low enough concentration that the sun will shine. And that is only one part of the forecasting problem. Quite frankly I think given the magnitude of the problem of measuring the atmospheric system, describing it and predicting its' future, modern weather forecasting is amazingly accurate and my forecasting colleagues do an amazingly good job. A good job of serving both the public and the private sector with accurate and timely forecasts.

ROLE OF PRIVATE SECTOR

For many years it was the view of the government and federal weather services, then called the "Weather Bureau" that there was little or no role for private weather services or private forecasts in the dissemination of weather information. Happily that view began changing in the 1950s and we now have a strong private sector in meteorology, that compliments and supports the role of the public sector.

If we agree that one of the fundamental functions of government is the protection of the lives and property of its' citizens, then few government organizations meet that function day in and day out like the National Weather Service. The mandate of the National Weather Service has been and should always be the dissemination of public forecasts and the issuance of watches and warnings required to safeguard the lives and property of the citizens. Sometimes as we have just seen so graphically in the case of hurricane Hugo, an excellent forecast can save lives but do little to allow for complete protection of property. Complimenting this broad mandate is the work of the private sector in meeting the needs of specialized groups, localities, industries or other users of weather information or products. The specialized needs may run from a trial lawyer who wants to know if the ground was snow covered on a certain date to a power company that wants a display of cloud to ground lightning strokes in their coverage area. Interestingly as the science of meteorology has made significant advances and we have been able, over the years, to use the best of American science and technology to tackle the forecasting problem, these advances have opened new industries and created significant growth in the private sector. Twenty years ago seeing a weather satellite picture on television was a rare treat. Now people even in the smallest towns can see colorized time lapse images of their weather, generated thousands of miles away by private companies and transmitted by communication satellites to TV stations in markets all over the country. It's even possible to watch the weather 24 hours a day on a cable channel. As with so many areas of science, as we have learned more, we have found more uses for what we have learned. Good old American initiative is alive and flourishing in the private meteorology sector. The private sector's development has almost always been in areas which serve the needs of users which would compliment the fundamental role of the National Weather Service. As the private sector has grown, there have been few areas of conflict with the NWS, and I feel a good positive professional working relation continues today.

SOURCES OF WEATHER INFORMATION FOR THE PUBLIC

As the private sector had grown the sources of weather information available to the public have also grown. Years ago, with little if any private forecasting, the weather forecast, whether in newspapers, radio or television was the "official" forecast. Now the public, in large metropolitan areas, may get a variety of forecast information in print, radio or TV. As the science of meteorology has advanced it also seems that the public's appetite for weather information has increased. Twenty years ago a five day forecast or outlook was impossible, now most folks expect a forecast for the weekend by Monday or Tuesday. The dissemination of weather data and weather forecasts to the public has gotten better, more extensive and more timely over the years but it can not be done without a strong working relation between the public and private sector. The best forecast is worthless if no one hears it and the most timely warning does no good if no one acts on it.

The role of the National Weather Service in being the critical fundamental source of weather data and weather products, (raw data, computer outputs, radar and satellite data) made available to all users, and being the source of public forecasts and weather warnings should not change, and if necessary should be reaffirmed as strongly as possible. The private sector, which has grown so much, and plays a vital role in the dissemination of weather information and specialized services, can not meet its needs if the free flow of needed data and products is diminished in any way because of modernization. The continuous flow of all weather data is critical to broadcast meteorologists. The quicker timely weather data and information can be provided, the more credible the information, and the more likely the public will be to take action if it is warranted.

MODERNIZATION AND THE PRIVATE SECTOR

I think all meteorologists agree that the modernization efforts of the NWS through the implementation of the NEXRAD network nationally, GOES-NEXT, automation of more observing sites (ASOS), more remote sensing such as

Profiler, the ALERT system, and the centralization of operation and greater computer capacity, will result in better forecasts, better forecast products, and faster dissemination of critical watches and warning to the public. Critical attention needs to be paid that these programs are maintained at needed funding levels and put into operational service without budgetary or political delay.

The current GOES-6 now provides the only continuous coverage for the United States and concern is mounting in the private sector that the first GOES-NEXT spacecraft may not be launched (now scheduled for mid 1991) prior to some failure of GOES-6. Because of the critical need for continuous weather satellite coverage, every effort should be made, including increased funding or changing launch priorities, if necessary, to insure service of the first GOES-NEXT before GOES-6 spacecraft failure.

As the modernization program continues, continued access to all necessary weather data and NWS or National Meteorological Center products should be assured, and planning should be clearly spelled out for continued access by the private sector to the needed data. NEXRAD has been in planning for many years and field installation is beginning but procedures and plans are only now beginning to be spelled out as to how NEXRAD products will be available to broadcast meteorologists and to other outside users. NEXRAD is a powerful meteorological tool and will provide NWS and private meteorologists with new information which will improve short range forecasts and warning lead time during severe weather. Access to these critical products for private meteorologists and especially broadcast meteorologists will benefit many users and provide the public with additional information and confidence in necessary watches and warnings.

People who hear weather warnings without seeing what the danger is, or any understanding of the basis of the warning may not feel a need to take action. People in the watch and warning areas of hurricane Hugo were more apt to heed warnings and take action after seeing the destruction in the Virgin Islands and also seeing dramatic satellite imagery of Hugo moving toward the coast. Similarly the use of NEXRAD by broadcast meteorologists to show areas of potential flood producing rains and circulations which may be tornadic signatures is certain to encourage confidence in the forecast and generate action rather than what could be critical delay.

All new products and data generated as the result of modernization should be as easily available to the private sector as NWS data and products are now and this should be reaffirmed to the private sector. No one would benefit by making access to new data difficult or restricted. It also continues to be critical to maintain the excellent working relation the private sector enjoys with the public sector. The proposed modernization of the NWS can only benefit the private sector and lead to improved public forecasts but it is critical that as part of the modernization the access of data be as open as it is now.

Public Response to Closure of Weather Offices

One area of the NWS modernization which has received criticism is the centralization efforts which will result in closing many smaller NWS offices and part time offices. There is legitimate concern by people in the local NWS areas of responsibility that they will not be as well protected by a forecast office which may be hundreds of miles away rather than local NWS office which may have served the community for years. The modernization effort including the national NEXRAD network, Profiler, GOES NEXT, ASOS and the next generation of atmospheric computer models along with improved communication systems will indeed produce more accurate and more timely forecast. However it is important that during the transition time, as modernization goes forward, there be a vigorous education effort to inform the public about modernization and centralization, what the advantages are, how the forecast products will be improved and how the public even far removed form a centralized forecast office will be given even better coverage and protection. This an area that needs cooperation between the NWS and the broadcast meteorologist, to insure that the public continues to be well served and understands what the modernization will accomplish. But a major effort is needed in informing and education the public.

PUBLIC RESPONSE TO HURRICANE HUGO

Hurricane Hugo will go into the record books as the most costly hurricane ever to hit the United States. I personally feel the NWS and in particular the National Hurricane Center, did an outstanding job of keeping the public informed about the course of the hurricane, issuing the watches and then warnings which allowed for an orderly evacuation and kept the loss of life to a very low number. The track of Hugo after it came ashore was more to the west than NHC guidance but, the track did follow guidance from the current operational national forecast computer model, the nested grid model. The NGM has been the principal operational model for only three years and has not had to deal with any category 4 hurricanes moving into the U.S. coast so there would be a reluctance to accept a somewhat untested forecast solution against the NHC hurricane models. In any event, although the warnings further north along the coast to New Jersey, Maryland and Delaware were later taken down as Hugo's path was well to the west, I received few complaints about unnecessary precautions, as anyone could see the serious potential of the hurricane looking at the damage to South Carolina and North Carolina where tornadoes were spawned by Hugo.

Without the media coverage of Hugo, the dramatic satellite pictures, that the private sector and broadcast meteorologists where showing, and the scenes of destruction in the islands, the public response to warnings may not have been enough to minimize the loss of live. Indeed the relatively low loss of life from this tremendous hurricane is a credit to the advances in the science of meteorology and communication systems we now have. A similar hurricane 50 years ago most certainly would have resulted in the loss of hundreds or even thousands of lives.

Hugo also gave us another reason to see that the funding for hurricane reconnaissance aircraft not be cut or reduced. During the critical nighttime hours before landfall, aircraft were continually probing Hugo and the aircraft were able to measure some strenghtening, and an acceleration in speed, and give critical information to forecasters to better prepare the coastal location were landfall was made. Any cutback or termination of hurricane reconnaissance aircraft would only make the hurricane forecasters more difficult and could unneccessarily risk lives along the coast.

The media coverage of the progress, landfall and damage form hurricane Hugo was intense and the ratings for all network and local news programs during this time were among the highest of the year. People were concerned about Hugo and wanted as much news, guidance, and forecast information as possible. One individual stood our during this time. Dr. Bob Sheets, director of the National Hurricane, made himself available around the clock to all national and local news programs. His information and discussions were always geared to keeping everyone informed, raising concerns were necessary, while avoiding unecessary speculation, while remaining calm and deliberate. His discussions about the eventual path and danger of the hurricane were a critical source of information and reassurance to the general public. In such times of life threatening weather it is important, if the warnings are to be heeded, that the public not be subjected to conflicting information or conflicting forecasts. That the director of the National Hurricane Center could be seen and heard by so many in the watch and warning areas, I feel, went a long way to getting the necessary public response and action to minimize the loss of life. The cooperation of the public and private sector during hurricane Hugo is another example of how the entire meteorological community works together to provide the best forecast information and weather data to the public. There have been occasions in the past when some private forecasters have issued their own "hurricane" forecasts or hurricane track forecasts. I question how such conflicting information can serve the public or how an individual forecaster can justify a forecast without having all the model outputs and detailed data and information available to the National Hurricane Center. Routine day to day forecasting is quite a different procedure for the private or broadcast meteorologist than trying to forecast hurricanes. At the minimum, I feel it is the responsibility of any broadcaster to give viewers or listeners the "official" hurricane forecast track from the National Hurricane Center, and any personal forecast be explained on the basis of solid meteorological reasoning and not "grandstanding". No one is served by confusion during life threatening weather. Such responsible cooperation and service should also be the aim of private and broadcast meteorologists during tornado watches and warnings.

FUTURE OPPORTUNITIES AND PRIORITIES

For both the public and private sector, the modernization plans and changes to come in the next few years in the National Weather Service, are critical to keep on course with a minimum of delay. Because of some delays in the past due to budgetary or political decisions, implementing the necessary changes and advancements in the three critical areas of satellite, radar and surface observations as smoothly as possible may be difficult.

The nation's weather services are on a path which will give the country ever better, more accurate and more timely weather forecasts and warnings. It is imperative that the plans developed and now underway be vigorously supported and funded. We have seen some delays in NEXRAD because of funding uncertainties in years past. Several years ago there was consideration given to only having only one polar satellite and now without sufficient backup in the GOES program we may lose our one geostationary weather satellite before the first GOES-NEXT can be launched. How prepared would we have been for hurricane Hugo without a GOES spacecraft? We have fallen behind the European community in computer power and speed in weather forecasting because new systems have not been funded and acquired as rapidly as they should have been.

We have the best pool of scientific talent, computer know how and space technology in the world. The one science which can benefit the most from these areas and be of greatest benefit the the general public is the forecasting the weather and safeguarding our citizens from weather related natural disasters. The weather services of the future, with the continued cooperation of the public and private sectors, and continued access to all available weather data, will insure that the public is better informed, understands what is likely to happen, will be given more accurate information with a longer lead time during severe and life threatening weather and will continue to support and see the benefit of our nation's weather services and the needs for continued research on the many atmospheric problems.

Meteorologists, both public and private are a group of dedicated, thoroughly professional scientists who provide enormous and often unappreciated and unrecognized service to our country, but a group of dedicated scientists who could do even better with continued support and increased funding.

Once again, my thanks to the Chairman and the Committee for the opportunity of presenting this statement.

Senator GORE. Our final witness is Dr. Kerry Emanuel. Thank you very much for being here.

Please proceed.

STATEMENT OF DR. KERRY EMANUEL, CENTER FOR METEOROLOGY AND PHYSICAL OCEANOGRAPHY, MASSACHUSETTS INSTITUTE OF TECHNOLOGY

Dr. EMANUEL. Thank you, Mr. Chairman. It is a pleasure to be here today.

I have divided my testimony into two parts; one deals with the issue of climate change and, in particular, its effect on small-scale destructive weather systems, and also what we need to know about small-scale weather systems in order to deal with climate change. And I would also like to address a few remarks toward the modernization plan for the National Weather Service.

Now, it has been stated here earlier today, and in fact everyone has heard from the press that there is a consensus among the scientific community that there will be a significant warming in the climate.

Mr. Chairman, I do not agree with that. I spend a lot of time talking to my own colleagues on this problem. There is no scientific consensus that there will be a warming; none whatsoever. And the reason for that is very simple and it has already been stated. There are simply tremendous uncertainties in this problem.

It is really a reflection of our collective ignorance, something that we are very much trying to do something about.

Let me illustrate for you by example, if I might, where some of these uncertainties lie. I happen to work in a branch of meteorology that deals with small-scale convection. Among other things, convective clouds transport water vapor in the atmosphere.

Now, one of the little secrets of the subject is that the most important greenhouse gas in the atmosphere is water vapor, far more so than carbon dioxide. But the way water vapor is regulated in the atmosphere is very different from the way carbon dioxide is regulated. Frankly, we do not understand it. We do not understand either issue.

The climate models on which these estimates are based turn out to be extremely sensitive to little tiny details in the way you do things, like transport water vapor in cumulus clouds. For example, the British meteorological office recently published a paper in which they tweaked one little parameter that governs the amount of liquid water in cumulus clouds and the global warming went from five degrees to one degree.

Now I am not sitting here telling you that global warming will not occur, I am sitting here telling you there is no consensus that it will; the uncertainties here are terrific.

What is the real limitation here? How come we are in this position? I would argue there are two main problems that have to be addressed, and one is funding.

Let me state for the record that in the last few years, the geosciences division of the National Science Foundation has been the bottom man on the totem pole in funds. That is, we do not really see an enhancement of funding going into the scientific research on climate change. And I think this is really problematic.

For example, the National Center for Atmospheric Research (I am on the board of trustees of the corporation that runs that organization), has had serious cutbacks over the last few years. Some of their senior staff have left. And this is one of the main centers for climate research.

I simply do not understand why this is happening.

The other limitation is talent. There are some very talented people working on these issues of climate change, but not very many. I think all of you, if you really looked into this, would be surprised. If you look at the number of papers that are actually published in scientific journals that deal directly with climate change, it is very small, less than a dozen per year.

Frankly, the problem is that we are having a hard time getting good students to come in and work with us. This is a problem in all the sciences, but I think it is particularly critical in our science, because no one argues with the idea that these scientific problems need to be addressed. And the sooner we can make a definite prediction or a more definite prediction, the less likely it is that we will either be unprepared for climate change, on the one hand, or waste a lot of money preparing for something that turns out not to be significant at all, on the other.

Let me very briefly address one of the issues I was asked to address. I have done some research on hurricanes; it is one of my main research interests, and we do believe that if the tropical ocean temperatures were to go up, that this would mean an increase in the intensity, but not necessarily the frequency of hurricanes—and possibly a very substantial increase.

And I entirely agree with Bob Sheets' remarks that we have absolutely no evidence that this kind of increase has occurred so far. We simply do not see a trend in the tropical ocean temperatures, but it is something that we need to be worried about.

Now let me very briefly address, from a slightly different point of view, the National Weather Service modernization plan.

I would like to preface my remarks by noting that I sat in front of this committee about two years ago, in 1987, on a hearing about the NOAA budget. And at that time I was sharply critical of the National Weather Service and some of its programs and plans. Those remarks are in the public record, and I will not repeat them here.

But let me say very definitely that in these last few years the amount of progress that has been made is absolutely staggering. I really take my hat off to Dick Hallgren, Joe Friday and the other people who have worked so very hard on this modernization plan. I personally feel that it is an excellent plan and one that the entire country should be behind.

Now I view my job sitting before you as a witness, to ask some tough questions, so I will do that. But I want it understood that I feel that, in general, this plan is very, very excellent.

Am I, by the way, running overtime here? Please stop me.

Senator **Gore**. A little bit. If you could conclude very soon. But I do not want to cut you off. Please proceed.

Dr. **Emanuel**. All right. I will try to wrap it up.

No one disagrees that the principal mission of the National Weather Service is warning of life- and property-threatening weather.

I would also add to that, as Mr. Ryan did, that I believe one of their duties is the collection and dissemination of meteorological data. This is the data that allows the private sector to do its job, which is a very important one; it allows the universities to do its job in research, and this includes global change research; and very importantly, in education. And some of the students we educate are students who eventually work for the National Weather Service.

So I would add that, if I had the opportunity, to their list of duties.

It is more problematic whether the National Weather Service should continue to be involved in forecasting of non-life and property-threatening weather. And here I believe that a symbiotic relation with the private sector is the optimal way to proceed.

Now, I am concerned, as Mr. Powell was, that we cannot do anything with the new technology—I wish I had time to talk about it, because I think it is very excellent technology—unless we have very good people using this data.

Now we have seen efforts by the National Weather Service to reach out to the universities and to others to cooperate with us in the training of future Weather Service employees, and we have seen training programs, and I think we are moving in the right direction here.

But I am concerned, from a slightly different point of view, about the distribution of proposed weather forecast offices, from the point of view of human beings, not numbers of human beings, but their jobs. In my view, an effective weather forecast office is one in which people are highly trained, are kept abreast of what is going on, and are highly motivated.

Frankly, I do not think you can do that in certain parts of the country in which a weather forecast office issues one or two or three warnings a year. That is just not enough.

I would like to suggest that there are certain parts of the country in which the proposed number of weather forecast offices is too many. I would centralize. And I would do so from the point of view of making the job of the forecaster more interesting and more responsible.

There are other parts of the country, on the other hand, in which we have too few offices, where the proposed plan will result in an overload of the staff.

And so let me simply conclude by saying I wish that the proposed distribution of offices reflected the distribution of severe weather and not monetary or political considerations.

And that is really all I have to say.

Thank you.

[The statement follows:]

STATEMENT OF DR. KERRY A. EMANUEL, MASSACHUSETTS INSTITUTE OF TECHNOLOGY

Mr. Chairman and Members of the Committee:

I am a professor of meteorology at and Director of the MIT Center for Meteorology and Physical Oceanography and have been engaged in research and teaching in the atmospheric sciences for eleven years. My areas of specialization include mesosacale and tropical meteorology. I serve on the board of trustees of the University Corporation for Atmosheric Research, which will be managing the Center for Operational Meteorology, Education and Training (COMET) of the National Weather Service.

In this testimony I would like to remark on some recent research on the effects of global warming on life-and-property-threatening storms and to comment on the National Weather Service's modernization plan in the context of severe weather warnings.

Global warming and destructive storms

The amount of carbon dioxide and other trace gases that absorb radiation have been steadily increasing over the past several decades. These measurements are quite clear and there is no debate on this point; at projected rates of fossil fuel consumption the amount of CO_2 in the atmosphere will have doubled by sometime in the late 21st century. This is the only aspect of global change that is not debatable. You have no doubt heard that virtually all the model studies predict a substantial warming (2-5°C) as a consequence of the increase in CO_2 and other gases such as methane. It is also true, however, that all these models reflect a serious lack of understanding of several physical processes at work in the atmosphere, biosphere, and oceans. Let me give you a few examples. One of the most important means by which heat and water vapor (the most important greenhouse gas) are distributed in the atmosphere are cumulus clouds, which are much too small to be incorporated in climate models. But as they are very important, they must be represented in the models by ad hoc parameters. These representations are presently so crude that a small improvement to them could conceivably reduce or increase the projected warming by 5°C. Similar gaps in our understanding are reflected in the treatment of global cloudiness and in the coupling of the atmosphere with the oceans. The uncertainties presently associated with climate modeling are so large that it is difficult to attach much meaning to the results. Among serious scientists there is absolutely no consensus that there will in fact be a significant warming in the next century.

Nevertheless, global warming remains a possibility, within the limited realm of our present understanding. It would seem prudent to encourage scientists to reduce the uncertainties by accelerating their research in this direction. We are limited in this effort principally by the very limited flow of talented students into our field. It may also be prudent for the society to be aware of the possible effects of climate change in a worst case scenario. I feel I ought to describe this worst case scenario for you. What I will now tell you is very much within the realm of possibility, given our present state of ignorance, but it is important to point out that there is a roughly equal probability that nothing at all will change. I will focus on the possible effects of climate change on severe storms, as this is one of my areas of research and as it directly pertains to the NWS plans for modernization.

Hurricanes are one of my interests. I can assure each of you that had you time to sit down with me and learn about how these magnificent storms work, you would be overpowered by their beauty. But on to the matter at hand. We are reasonably certain that *if* the tropical ocean temperatures were to increase by 2 or 3°C, the wind speeds of the most intense hurricanes would rise by about 25%. As the destructiveness of hurricane winds increases with the square of the wind speed, this translates into an increase of the destructiveness of hurricanes of about 50%. How do we know this? Figure 1 shows the maximum wind speeds of recorded hurricanes as a function of the ocean temperature. Note that at a given sea temperature, there can be hurricanes of quite different intensities. But the important point to note is

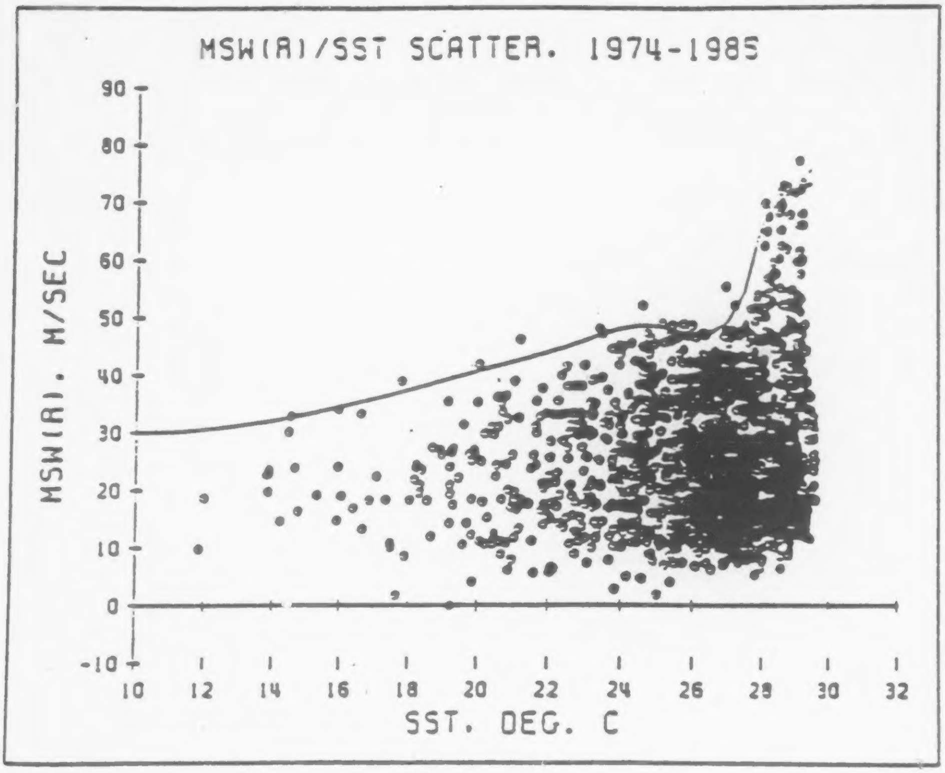

Figure 1. Scatter plot of maximum hurricane wind speeds as a function of sea surface temperature (SST). The solid line shows the upper limit on intensity. Figure courtesy of Robert Merrill.

that there is an upper limit to how intense you can make a hurricane at a given sea temperature. This is given by the heavy curve in the figure. This curve was drawn based on the data alone by the scientist who did the data analysis, but it almost exactly coincides with the upper limit deduced from theory. So from both the data and the theory, we are pretty confident that we know the upper limit on hurricane intensity as a function of sea surface temperature. Notice how sharply this limit increases at warm temperatures. Hurricanes such as Gilbert and Hugo are examples of storms that approach the upper limit of intensity. Although only a few hurricanes reach this limit, they are the most destructive storms. One can see from Figure 1 that if the ocean temperature were to increase to, say, 32°C, we would have a real problem. By the way, the *frequency* of hurricanes is another matter entirely. We have no real way of knowing whether the frequency of hurricanes would increase or diminish if the climate warms.

The two greatest natural catastrophes in U.S. history were both hurricanes: the Galveston storm of 1900, which killed 6000 people, and the Okeechobie hurricane of 1928. The loss of life in each of these storms far exceeded that of the great San Francisco earthquake of 1906. The loss of life in the United States has been dramatically reduced by the work of the National Hurricane Forecasting Center, in cooperation with civil defense and other agencies and with the aid of modern technology, particularly radar and satellites. I am a tough critic of bureaucracies, but the Hurricane Forecasting Center is an agency that works extremely well. It is sobering to reflect that in 1970 a hurricane in Bangladesh killed 300,000 people and that Hurricane Hugo did about as much damage in Puerto Rico and the United States as did the recent earthquake in California. The loss of life in hurricanes is less only because we can now see them coming. Even so, we could be doing a better job forecasting more accurately where a hurricane will make landfall. When we are wrong, tremendous sums are spent in needless preparations. The primary limitation on making better short-term forecasts is the lack of sufficient measurements of the atmosphere over the oceans. This is a point I will return to in discussing the weather service modernization plans.

The big killers in the U.S. are lightning, tornadoes, and flash floods. Unlike hurricanes, tornadoes and flash floods develop and dissipate in a few hours or less and thus constitute a much tougher forecasting problem. All of these phenomena are aspects of atmospheric convection, which is likely to increase in intensity if the climate warms. It is to these phenomena that most of the National Weather Service modernization plans are rightly addressed. Lightning alone kills more people each year than did the recent San Francisco earthquake, and much of this death is probably preventable.

The National Weather Service Modernization Plans

a. What is the mission of the National Weather Service?

In a recent document entitled *Strategic Plan for the Modernization and Restructuring of the National Weather Service,* the NWS asserts that its mission is "to provide weather and flood warnings, public forecasts and advisories for all of the United States, its territories, adjacent waters and ocean areas, *primarily for the protection of life and property"* (emphasis mine). There is a subtle but important issue here as to what NWS means by "primarily." There is no doubt that NWS is engaged in a move away from the routine forecasting of non-life-and-property-threatening weather as the private sector gradually takes over this function. This trend is reflected in NWS modernization plans, which rightly focus on its warning function, but in my view they do not go far enough. There is no reason that routine forecasting should not be left entirely to the private sector. In Boston, where I live, all the media have their own meteorologists and no one ever hears an NWS forecast, but the taxpayer pays for it anyway. There are only two reasons to have an NWS forecaster in Boston: 1) to collect observations (which machines can do automatically) and 2) for the 1 or 2 days a year when that forecaster earns his pay by providing timely warnings of severe weather.

In my view, the task of providing severe weather warnings is best served by regional rather than local offices. By having, say, one office serving all of New England, New York, and New Jersey, rather than the present plan for nine, and five (as opposed to two) offices in Oklahoma, one achieves not only an economy of scale but a potentially large increase in the quality of service. Permit me to explain why I believe this would be so. In a region whose size is chosen so that severe weather occurs with moderate frequency, skilled forecasters equipped with the appropriate technology would be kept in a high state of training, in contrast to the present state of affairs in which local forecasters in areas where severe weather is rare are often ill equipped to deal with the severe weather that occurs once every few years, while, in areas prone to severe weather, staff are overworked. This past summer, a destructive tornado occurred near Boston. The local NWS office did not issue a warning for this storm despite being informed by their own radar operator of radar signatures characteristic of tornadoes and despite being informed that a dangerous tornadic storm was being observed on a Doppler radar operated by MIT. This failure is likely to occur in regions in which severe weather is rare. In contrast, the warning function is usually carried out very effectively in those parts of the country where severe weather is frequent, simply because the staff has more experience with such weather, though such staff may be frequently overworked. Logic dictates that the distribution of NWS forecast offices should reflect the distribution of severe weather. I am afraid the proposed distribution is based more on politics than on logic. The present plan makes sense only if the NWS wishes to compete with the private sector in making routine forecasts. I believe that the NWS is missing an opportunity to improve service *and* perhaps cut operating costs.

b. The proposed technological improvements

The NEXRAD network represents an excellent plan to upgrade the nation's radar capability, long overdue. This technology should vastly improve our ability to make short-term forecasts of severe local weather events. There is strong support for this proposal in virtually every segment of the meteorological world. The lives saved by this technology will be well worth the cost.

The Automated Surface Observing System (ASOS), upgrades to satellites and to National Meteorological Center (NMC) computers are all badly needed features of the modernization plan. It appears that the NMC forecast models are now up to the standard of the European Centre for Medium Range Forecasting, thanks to better computers and more lively interactions with scientists outside of NWS.

Although the NWS view of its own mission quoted previously does not mention the collection and dissemination of meteorological data, nor does it discuss the operation of NMC, all these tasks are viewed as vital functions or the National Weather Service. These functions are vital not only to the NWS mission but to thousands of laboratories and universities worldwide that use data in education and research and to the private sector which uses it in specialized forecasting.

The backbone of the observation network is the weather balloon, or rawinsonde. Although not explicitly mentioned in the modernization plan, an upgrade of this system is especially needed. One very major gap in the observing network is the lack of upper-air data over oceans. Until a few decades ago, weather ships launched such balloons routinely. Now there is less useful data over the oceans, in spite of the advent of data buoys at the surface and commercial aircraft observations at high altitudes. The development of automated rawinsondes launched from commerical ships, already under way, would do more for forecasts and warnings than all the meteorological satellite data currently available.

A very important feature of weather service modernization is NOAAPORT, a system by which real-time meteorological data is to be transmitted to users outside of NOAA. This will make it much easier for other research laboratories, universities, and the private sector to make full use of the nation's data resources. NOAAPORT is extremely important to the future of meteorological research and to effective forecasts by the private sector. This project should not be sacrificed.

The development of the next generation observing systems, of NOAAPORT and of AWIPS have not, to my knowledge, benefitted from open dialogue with either universities or the private sector, who will be among the largest users or the data. This is very unfortunate.

c. *Hiring and employment practices*

It is my understanding that the new Weather Forecast Offices will be staffed at a somewhat higher level than is currently the practice. This is a welcome change. I am, however, concerned that the emphasis is too much on the machine side of the man–machine mix. Human beings with experience are far more efficient than machines at recognizing dangerous patterns, and the new systems ought to recognize this. The weather service has suffered from too much reliance on technology. For example, individual forecasters are strongly discouraged from issuing forecasts that depart significantly from computer guidance, thus relegating human beings to the role of merely putting numbers into words. Moreover, individual forecasters are strongly encouraged to move quite frequently, so that whatever experience they gain is rapidly lost. These practices guarantee that we will wind up with "civil servants" who are, as Winston Churchill described them, neither.

3. Summary

Severe weather events take enormous tolls in life and property each year in the United States. There is a risk that severe activity will increase over the next several decades. The weather service modernization plan will put into place technology that will radically improve our ability to provide timely warnings of tornadoes, lightning, flash floods, and strong downdrafts that threaten aircraft, and will somewhat improve our ability to pinpoint hurricane landfalls. I believe that the overall plan is an excellent one. At the same time, there are several issues that, in my view, need to be addressed:

- NWS should reconsider whether it should remain in the business of routine forecasting, as opposed to warnings and advisories, in view of the successful adoption of the routine forecasting function by the private sector.
- The distribution of Weather Forecast Offices should more nearly reflect the distribution of severe weather. Large parts of the country could do with fewer offices while some others would profit from a greater number. This might cut costs and would improve service as each office would have just enough to do to keep the staff in a high level of training and enthusiasm for their jobs.
- The planning of the next generation of weather observing systems, of NOAAPORT and of AWIPS should not proceed in isolation from the large community of users outside of NOAA, as has happened in the past with poor results.
- There should be great emphasis on the human element of severe weather forecasting. The forecaster of the future must be highly trained and highly motivated by making full use of his talents and according him the freedom of judgement crucial to success and to job fulfillment. Rotating shifts and frequent transfers to other locations are a strong disincentive to high quality staff, and the experience built up at one location is lost in the transfer to another.

Senator GORE. Thank you very much. We really appreciate that testimony.

Dr. Halgren, as past director of the National Weather Service, I know you understand better than most the importance that this committee has always placed on the modernization of the service. And I know you had a great deal to do with initiating the modernization plan that we are reviewing today. Unfortunately, I expect that OMB also played a very significant role in shaping that plan.

Could you just very briefly point out what you believe to be the shortcomings of the current plan as we now have it?

Dr. HALLGREN. Well, I think generally the plan is a very good plan. I am concerned in just a couple of areas. I am going to exclude commenting on Alaska; that area is different from the lower 48. I think Joe Friday said earlier today that he will take a look at it.

I am concerned in a couple of areas. One is that the numbers of people in the Weather Service offices will not be adequate to make full use of the technology, the point that Kerry just made here a minute ago. People get obsessed with reducing the numbers of people.

The second thing is to make sure that we have adequate contact with the local communities, the local emergency management agencies, media and other local groups. And that is why I mentioned in my testimony we are going to have to be very careful, and that it might be wise that we leave one or two people in the existing offices, even if they are not issuing warnings there.

If you cured those two areas, we would be in good shape.

I am confident that whatever problems are in the technology, that will be sorted out along the way. The programs, as far as I have been tracking them are running quite well; they always have troubles along the way. But those are the two issues.

Senator GORE. Very good. I am going to follow up, as other Members of the committee will, with questions for the record.

Dr. Hallgren, I know you have been centrally involved in the Decade of Natural Disaster Reduction proposed to start next year. I hope that for the record you could bring the committee up to date on the progress in this international effort. We will in another subcommittee, the Subcommittee on Space, Science, and Technology, be looking at that a little bit later on, but I would appreciate your supplying that for the record. I know that is near and dear to your heart.

Dr. HALLGREN. Let me say it is being debated in the General Assembly at the United Nations this week, so it should be coming out shortly.

Senator GORE. Great. I am looking forward to that.

Bob Ryan, you talked about the interaction between the public and private weather prediction services.

In your professional opinion, what would be the impact on daily forecasts that the American people get and on severe weather warnings if we were to find ourselves without coverage by the GOES satellite that is up there now?

Mr. RYAN. It would, I think, certainly make our job much more difficult. Perhaps more importantly, I would be concerned that it would be a sign of a great step backward in American science and technology as seen by the general public.

We celebrated 25 years of weather satellites only a few years ago. It is still rather new and modern; yet, in a way we have gotten used to turning on the news and, in the case of Hurricane Hugo, seeing these dramatic time lapse pictures of the hurricane approaching the coast. If we all of a sudden did not have that, it would be quite a setback, I think. It would certainly make the forecasting challenge much greater.

I think there is concern in the private sector that we may be facing a critical few months, perhaps even a year, as the existing GOES 6 ages before the first GOES NEXT is ready. I hope we do not slip any more than we already have.

Senator **Gore**. I do, too. I want to echo your opinion on that. I was not entirely reassured by the response that we had from the first panel on that. I know that their response was in keeping with the official plan, but I am worried about it. I think we could face a period where they do not overlap.

We will have other questions for the record. If we were not running out of time, I would spend a lot more time with this panel because I really enjoyed your statements.

Dr. Emanuel, I do not want to take a lot of time to fence with you about what a consensus is and is not because that is not our principal topic here today. Maybe on another occasion we can invite you to come back and do that in some detail.

Let me just say that, first of all, your testimony as I understand it is that if the oceans warm, say, 2 to 3 degrees Centigrade, then you would expect to see an increase in the intensity of storms of approximately 25 percent in the upper range and an increase in their destructive power by 50 percent. Is that correct?

Dr. **Emanuel**. That is correct. That is based both on a theory that provides an upper bound on hurricane intensity and also on data. I provided with my testimony a graph which shows you this upper bound from the data as a function of sea surface temperature in the current climate.

Senator **Gore**. Right.

Now you quarreled with my use of the word "consensus." A study by the National Academy of Sciences in 1979 concluded that doubling the carbon dioxide concentrations relative to the preindustrial atmosphere would result in an equilibrium warming of 1.5 to 4.5 degrees Centigrade; correct?

Dr. **Emanuel**. That is correct.

Senator **Gore**. Subsequent reevaluations by the National Academy of Sciences in 1983 and in 1987 as well as the state of the art report issued by the U.S. Department of Energy in 1985 have reaffirmed this estimate; is that correct?

Dr. **Emanuel**. That is correct.

Senator **Gore**. Okay. Now that may not be a consensus. It is a strong opinion expressed by an awful lot of people, and if you disagree with it, that is fine.

Dr. **Emanuel**. I am really not saying that I personally disagree with it. Actually, it is true that I disagree, but I do not happen to believe that those two reports you cited reflect the consensus opinion as I understand it from talking to my colleagues in this country and abroad.

Senator GORE. I had the first hearings on this subject in the Congress about nine years ago. At that time the idea of global warming was presented as a fringe issue that only a few kooks would take seriously.

I happened to be exposed to it, incidentally, because as a college undergraduate one of my professors was Roger Ravelle, who was the one person responsible for including carbon dioxide measurements in the international geophysical year. In 1958, he was responsible for placing the monitors at the station at Mauna Loa.

In the middle 1960s as an undergraduate I listened to him present the initial data readouts from that carbon dioxide monitor. Of course, then monitors went to Point Barrow and elsewhere.

When I had that first hearing I invited Professor Ravelle to come. As I mentioned, the response on the part of many in the scientific community was, "Oh, well, that is just absolutely nuts. That is a science fiction story." Yet, since that time I have watched it move inexorably from the fringes of science into the mainstream of science.

The debate which exists now reminds me very much of the debate which occurred in geology when Dr. J. Tuzo Wilson and others first presented the outrageous fringe theory of continental drift and tectonic plate movement. The most established geologist of that time persisting on into the 1960s said there is no consensus on continental drift. Indeed, it is ridiculous to believe that continents move. They are way too big to move and could not have possibly ever moved. Tuzo Wilson and others who preceded him were hooted off the stage at various scientific fora by scientists who looked so closely at the details of geology that they did not see the big picture and did not challenge the assumption deep in their minds that continents are so big they do not move.

I believe there is a similar assumption going unchallenged on the part of many scientists today in the atmospheric sciences. That is, the atmosphere of this planet and the nature of this planet is so vast and so powerful any of its particular characteristics cannot possibly be overwhelmed by the activities of human civilization.

I do not believe that assumption is any longer valid. Just as elementary school students figured out that South America and Africa fit together long before the established geologists recognized that indeed they do, I believe that elementary school students can figure out today that if we are in the midst of destroying half of the living species God put on this earth in the lifetimes of the current generation, if we are doubling the level of carbon dioxide that existed in industrial times in the lifetime of the present generation, if we are quintupling the population of human beings on this earth in the lifetime of a single human being, indeed the collision of human civilization and the ecology of this planet is a real collision with consequences for ecology and the climate of the earth that are not uncertain any longer. We can say that changes will occur.

The uncertainty is how big will the effects be, when will each one of them first be measured, and the like.

The collision, in my opinion, is not only real but constitutes the most challenging imperative of our time. I have said on other occasions that the dialogue within the scientific community and the dialogue within the political community both operate according to different rules, guidelines, cultures, et cetera. When politicians hear scientists say this is terribly uncertain, they use that as an excuse for doing nothing. When a scientist says this is uncertain, sometimes the scientist really means we need a lot more research to figure out exactly what this is doing.

When you take one culture and another culture, science and politics, and try to get communication between them, it is sometimes like Hurricane Hugo hitting the coast of South Carolina. That is the bone I would have to pick on this. As I said, we really need about a week's time to do justice on that dialogue, but let me give you a chance to respond before we close.

Dr. **EMANUEL**. Thank you. It is very disturbing for me who has been in this business for a little while to see the science in a sense become politically polarized because generally speaking science, good science operates more or less independent of people. The scientists themselves are not necessarily aware of the political implications. But this cannot be true in this case because the political implications are so great.

And so scientists have had to do an awful lot of soul searching as to whether their stance as scientists ought to change in this regard.

Now, I think you know and you have sensed properly that the proper stance of a scientist as a scientist is one of a skeptic, and it is quite true that some of the very best and most interesting theories were thought to be completely crazy when they were first proposed. It is also true some of the worst theories. That is why science proceeds this way.

I happen to feel it is my duty as a scientist to you as a senator to simply tell you what we know and to be also very clear about what we do not know, and then it is your very tough job to decide what to do with that knowledge.

Senator **GORE**. What is your gut feeling if the effective concentration of CO_2 in the atmosphere doubles. Is it your gut feeling that that will lead to warming?

Dr. **EMANUEL**. There is no doubt it will lead to warming. It is just that it is possible that the warming will be imperceptible. You see, I guess my answer to your question is a very, very honest "I do not know."

Senator **GORE**. But there is no doubt that it will lead to warming?

Dr. **EMANUEL**. Yes, I would say that. It is almost inconceivable, but it might be a hundredth of a degree centigrade.

Senator **GORE**. What is your gut feeling that it will be, an order of magnitude larger than that?

Dr. **EMANUEL**. A tenth of a degree centigrade. That is certainly within the realm of possibility.

Senator **GORE**. Are you familiar with the record from the ice cores I mentioned earlier?

Dr. **EMANUEL**. Yes, and that is a very interesting record. What it shows is that temperature fluctuations in the past are almost perfectly correlated with carbon dioxide fluctuations.

Senator **GORE**. It is interesting, is it not.

Dr. **Emanuel**. The problem is that it tempts the non sequitur in the sense that there are some very good theories as to why the temperature change might have caused the carbon dioxide to change. There are also good theories that suggest the opposite. It might even be true that a third agent caused both of them to change.

This is the problem of science. It is very difficult in looking at historical records to figure out cause and effect in such a complicated system. It is a very beautiful system. It is very complicated, and it is a big job to figure out what is going on. And that is why these uncertainties exist, and I think the fact that it is uncertain does not in any way lessen its urgency, because if there is a 20 percent chance of a significant warming, 20 percent may not sound significant until you stop to think about it.

If I said there is a 20 percent change you would get run down if you walked out in the street, you probably would not do it. And this, of course, is a tough problem. The fact is that in our present state of ignorance we do not know that there will not be a big warming.

Senator **Gore**. What probability would you put on the chance that a doubling of CO_2 concentrations would lead to more than a degree's warming?

Dr. **Emanuel**. That is like rolling the die for me, but I would say it is probably on the order of 10 percent or larger.

Senator **Gore**. In other words, your view is that a doubling of CO_2 concentrations would lead to only a 10 percent probability of warming of as much as 1 degree?

Dr. **Emanuel**. I would feel much more comfortable with the answer that I do not know, because I think it is an honest answer.

Senator **Gore**. I understand, and I pressed you for your gut feeling but, again——

Dr. **Emanuel**. My gut feeling is that we should be worried about it as scientists and as citizens. My own personal feeling is that we need to accelerate research. Whatever else we do, we need to accelerate research in this area.

Senator **Gore**. Just to fill out the record just briefly here, over the last 160,000 years CO_2 concentrations went up and temperatures went up in tandem. The combination when you put the graphs together, it is almost an exact correlation, and in the last interglacial period I believe it was about 300 parts per million. Now it is over 350. It may go to the equivalent of 500 to 600 within the lifetimes of people in this room. It has never been anything like that, and whenever it has gotten higher, the temperature has also gotten much higher.

We are going to go not just to 300 to 350 where we are now, but to 500 or 600, and you think there is only a 10 percent chance that that will be associated with a temperature increase? That is only a fraction of what happened the last time; it was half as high as that CO_2 level?

Dr. **Emanuel**. Given what I know about what we collectively do not know, I think that is a reasonable estimate. The number of things that can kick in here to compensate for that is very large, and unfortunately most of them are unknown, but we are not very far from knowing them.

Now, you see, I guess I would have to say I would not be at all surprised if we saw a big warming with the doubling of CO_2. It would not surprise me if we saw nothing.

Senator **Gore**. You say there is a certain chance that there will be nothing. Would you say that there is an equally large chance that the warming would be twice as bad as what the NAS predicts?

Dr. **Emanuel**. Yes, it could very well go in that direction, Senator.

Dr. **Hallgren**. May I make a comment?

Senator **Gore**. Yes.

Dr. **Hallgren**. It seems to me we have something very similar to earthquake predictions. For example, out in Parkfield, California, you have about a 50 percent chance of an earthquake of a certain magnitude in the next *x* years. In this case and in the case of global warming, we have a certain probability, and it is debatable of warnings in the coming years. Kerry has one view, others have other views. It is a very complicated problem. But there is a certain finite probability that we are going to have global warming. And it is time in my mind that the nation thinks of how to gradually respond to this as our knowledge increases as to what really will happen.

There are certain steps that we should be taking and getting underway, and I hope this nation and this world does, move forward. That does not mean that we have to go all the way as you said earlier, Mr. Chairman.

Senator **Gore**. Well, let me just conclude. This is a hearing about the weather service, and we have appreciated your statements on the modernization plan and the other issues discussed.

I cannot resist one concluding comment because I do believe that the approach of science has at least as many problems as the approach of politics. I think since the beginning of the scientific method we have seen problems similar to the ones embodied in this principle they call the Heisenberg principle that the quantum physicists use.

You cannot observe something without changing it. The idea that we can coldly—coolly and in a calculated way—sit back and watch what happens when we double CO_2 concentrations on the earth, when one outcome of the experiment may be the destruction of the ecological system on which life as we know it depends is, in my view, an absurd approach.

It is unethical. It is unacceptable. We cannot continue it, and in the face of that problem, uncertainties about whether or not we will destroy the ecology of the earth ought to lead us to safeguard against that contingency.

We are part of the system we are observing. We are now a bigger force or may well be a bigger force in changing nature than any natural force. Anyway, you know my views.

I appreciate the chance to talk with you at the end of this hearing on the weather service, and I appreciate all of you coming. I am sorry for the length of the time that it has taken, but I appreciate your being here.

[Whereupon, at 12:45 p.m. the hearing was adjourned.]

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